Noise in early childhood education centres- the effects on the children and their teachers

A thesis

presented in partial fulfilment

of the requirements for the degree

of

Doctor of Philosophy

at

Massey University, Wellington,

New Zealand

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2008

Massey University Human Ethics Approval

This project has received full Massey University Human Ethics Committee approvals (Wellington 03/120 and 05/34). More details are given in Appendices 1.

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Abstract

Although the effects of noise on children's learning in school classrooms is well documented, there is very little on the effects of noise on preschool children. There are strict legal requirements for the daily noise exposure an adult worker can received in the workplace but nothing to control the noise children can receive in school and early education. There is also little or no data on how sound affects a child, compared to an adult. The early years of life are critical for the development of speech, hearing and auditory processes, as well as being the most vulnerable time for middle ear infections. This work sets out to determine the typical noise levels in early childhood centres and the effects on a range of children and their teachers.

Reverberation times in most centres were found to well exceed the 0.6 seconds prescribed by the Australasian standard for schools and learning spaces. Very high levels of noise were recorded in a number of centres with a significant number of children and staff members, exceeding the maximum daily sound exposure of 100% permitted for workers in industry. A range of special needs children were identified as being particularly at-risk to noise, with the most adverse outcomes reported for those experiencing sensory integration disorder. Yet, even though high levels of noise were recorded, the majority of respondents in a survey of teachers rated the lack of sufficient space for the number of children present as the main issue, and inclement weather as the greatest environmental condition contributing to noise (by confining children indoors, especially over long periods of time).

Hearing tests on the children were not permitted under the strict human ethics criteria to which this study had to conform, but simple hearing tests on a small group of teachers, revealed that hearing loss could be a serious occupational health issue. The legal issues of noise control and management in early childhood education have been addressed in this thesis, current legal frameworks reviewed, and recommendations presented for future consideration.

Acknowledgements

This project has involved a large amount of cooperation and assistance from a number of people and organisations, which I wish to acknowledge.

Firstly I would like to thank my scientific supervisors, Professor Philip Dickinson, and Associate Professor Doug Hay, and Dr Rachel Page, Wellington Director, Institute of Food, Nutrition and Human Health, for their constant help encouragement and advice. In particular, I would not only like to acknowledge Professor Dickinson's help with the preparation of this work, but in the preparation of the journal articles, conference papers and special reports directly attributed to this work. I would like to especially acknowledge the help and support of Dr Page and Ms Wilma Tielemans who assisted with the final reading of the thesis. Their input was invaluable. I also acknowledge the help and support of Dr Page in obtaining a Massey University Advanced Study Award and attendance at conferences.

I would like to acknowledge the contributions made by my wife, Debbie, in her unwavering support of this project and acknowledge the special contribution made by my autistic son, Julian. The direction this project took was greatly influenced by his experiences in trying to make sense of the world around him and the difficulties he faces.

I would especially like to thank Ms Sue Thorne, CEO, Early Childhood Council of New Zealand for her encouragement and support of this project as well as the considerable time spent reviewing the documents for the Massey University Human Ethics Committee approval.

Special thanks are due to the many specialists who assist and advise special needs children in their homes and early education centres. In particular I would like to acknowledge special contributions made by Speech Language Therapist, Lynne Hayes, team leaders, Jane Farmer and Susan Clark and their staff of Group Special Education, Wellington for sharing their experiences and their most valuable contributions to this project. Special thanks are also due to Barbara Price and Betty Maxwell (Gifted Development Centre, Denver) for all the information received on giftedness.

I would like to thank with gratitude all the childcare centres staff, and especially the children and their parents who so willingly contributed to and supported this project.

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1 Introduction

While hearing specialists and acoustical engineers in the USA have requested that acoustics be considered in the design of classrooms and learning spaces, it remains an issue largely ignored to the detriment of students and their teachers.[1] In New Zealand, there are numerous cases in preschool, primary, secondary and tertiary educational facilities where acoustical considerations have not been included in the design, building or refurbishment. This is largely due to the lack of criteria in building requirements for school classrooms and similar learning spaces.

While research to date shows that all children are potentially affected by noisy environments, the impacts will be the most severe for those with hearing impairments, and auditory function deficits such as autistic spectrum disorders and attention deficit/hyperactivity disorder. Children who are studying in their second language are also vulnerable. Research has shown that they perform more poorly than those studying in their native language.[1, 4]

Hearing impairment or other auditory function deficit in young children can have a major effect on their development of speech and communication, resulting in a detrimental effect on the ability to learn effectively at school. This is likely to have major consequences for the individual, and the population as a whole. The New Zealand Ministry of Health has found from research carried out over the last 2 decades that hearing loss affects 6-10% of children in New Zealand.[2] Early diagnosis of such conditions enables the child to be assessed for special education and educational support at regular childcare facilities. This is generally not available for children who may experience such conditions, but have not been formally diagnosed.

The International Institute of Noise Control Engineers (I-INCE), developed the Technical Initiative #4 -'Noise and reverberation in school rooms' as a recognition of the importance of this issue.[3,4] Few studies have been carried out in early childhood education in New Zealand and internationally, which is surprising as the early education years are critical for speech and learning development. Preschool children are vulnerable to high incidences of otitis media with effusion (glue ear). In serious cases (where this remains untreated), this condition can lead to permanent hearing loss.

A preliminary study in New Zealand[5,6] found that classroom noise presents a major concern for teachers and pupils. Modern teaching practices, classroom construction and means of ventilation all contribute to the number of children unable to comprehend the teacher's voice. Nelson and Soli[7] have suggested that the recent trends in learning often involve collaborative interaction of multiple minds and tools as much as individual possession of information.[8] This all amounts to increased activity and noise levels, which have the potential to be particularly serious for children experiencing auditory function deficit. Noise in the classrooms and similar learning spaces can only exacerbate their ability to comprehend and process verbal communication with other children and instructions from the teacher. Anecdotal evidence also suggests that teachers in preschool environments are exposed to considerable amounts of noise. Clearly, exploratory studies are needed to assess the various types of childcare facilities in New Zealand, the various conditions, which give rise to noise levels, and the typical noise exposures to which children and their teachers are subjected.

The typical levels of noise in early childhood centres are largely unknown due to the paucity of data on this topic. Very few studies have been conducted in New Zealand and internationally on noise levels in preschool education. However, anecdotal evidence from teaching staff suggests that this is an issue of concern for them and the children. The current early childhood legislation has a requirement that noise be kept to a reasonable level, which suggests that this has been an issue in the sector. As an enforcement or guidance tool for the control of noise, the present legislation is far from adequate. It is necessary to determine the typical sound pressure levels in a range of early childhood centres in New Zealand.

Personal sound exposures of young children have not been possible due to the lack of suitable equipment small enough to fit comfortably on to the clothing of young children. With the acquisition of new light-weight noise doseBadges, an estimation of noise exposure levels in early childhood education is now possible.

While teachers and other staff are covered by the provisions of the health and safety in employment legislation of New Zealand, the New Zealand Department of Labour, (the regulatory agency) has largely ignored this group of workers for exposure to occupational noise. This is probably due in part to the noise provisions of the legislation not being designed or envisaged for this group of workers. There is a need to determine the likely levels of occupational sound exposure among teachers and contact staff in the early education sector and determine whether or not they are at-risk of acquiring noise-induced hearing loss as a result of their work.

There has been no acoustical design criteria for schools and preschool classrooms in the building legislation and promulgated standards for classrooms and other learning spaces. Most of the schools and preschools do not have any acoustical treatment and therefore may have substandard conditions, which will accentuate noise levels and degrade speech communication. In addition, a number of early childhood centres are placed next to main highways, and other noise producing activities, with few means to attenuate noise intrusion from such external sources.

There is a worldwide trend to mainstream children with disabilities and special needs into mainstream education. This began in New Zealand with the enactment of the New Zealand *Education Act 1989*. Section 8 of the Act gave all children with disabilities, the right to go to school and to receive the same level of education as other children. It became illegal to refuse to enrol any child on account of their disabilities who were otherwise entitled to enrol at the school. Prior to this legislation, schools were not obliged to enrol disabled pupils and there were no targeted funds available to provide the extra support and resources needed. Special classrooms, in some cases, were set up on hospital campuses to provide education.[9] This wide-reaching legislation represented a major shift in the educational learning, welfare and treatment of special needs children. Special funds were established to provide targeted support for individual children at school according to need, along with a range of initiatives and support services for these children in school - i.e. speech language therapy, occupational therapy, behavioural management, etc. While early education is not compulsory, policies extended the rights of special needs children to be mainstreamed in early education. Medical and educational specialists widely recognise that to achieve the greatest benefit for special needs children, the earlier the intervention must be implemented for the child and hence the origin of the educational strategy, 'early intervention'. The New Zealand Ministry of Education has dedicated a high level of support and funding for early intervention strategies in preschool education. Unfortunately, the physical environment such as acoustic conditions and special facilities conducive to the special needs of these children have not been widely considered and is a major focus of this thesis.

The literature on noise in an educational setting, and on acoustical barriers to learning, indicates that children with intellectual disabilities and hearing impairment are likely to be most at-risk. Information on the extent of adverse outcomes or seriousness to such groups is sparse. However, clinical data and literature on specific disorders and personal communication with special education specialists reveal that there are likely to be children with a range of disabilities who are adversely affected. It is critical that the most at-risk groups are identified, and as far as possible, an investigation be made of the types of noise that affect them.

Strategies need be developed not only in classroom design but also in legislation and teaching practice, to ensure that children and their teachers are not placed in a situation where there is a risk of hearing loss or other harm to children and where there are barriers to learning. With the review[10] of the current legislation[11] in New Zealand, strategies and provisions can now be considered for the most at-risk groups.

1.1 Research questions

The following five research questions are proposed:

1 The sound environment

What are the typical noise levels encountered in a range of early childhood centres and by how much do they exceed the levels proposed by the World Health Organization for unoccupied classrooms?

2 Personal exposure

What are the likely personal sound exposure levels of the children and their teachers and how do these relate to the New Zealand and international occupational noise criteria?

3 Observed effects on children

How does noise affect the learning outcomes and well-being of special needs children mainstreamed in early education?

4 The physical learning environment

What is the general acoustical quality of early childhood centre learning spaces and do they comply with the recommended criteria for classrooms and learning spaces given in the current Australian/New Zealand Standard?

5 Strategies to mitigate noise levels

What strategies can be developed not only in classroom design, but also in legislation and teaching practice, to ensure that children and their teachers are not placed in a situation where there is a risk of hearing loss and where there are barriers to learning for special needs children?

1.2 Aims

The primary aim of the work described in this thesis was to determine the typical noise levels and exposure in early childhood education centres in New Zealand and critically examine how they affect the children and teaching staff. This included ambient sound level measurements in learning spaces of early childhood centres along with personal sound exposures received by staff and children. At-risk groups of children were identified and comprehensive information sought from the literature, questionnaires/interviews of teachers, special education professionals and parents as to how noise and the acoustical environment affected them.

A further aim was to critically investigate the physical parameters of acoustical environment and how this may contribute to noise levels.

To critically examine the current legislative frameworks and precedents for the control of noise in New Zealand legislation and to recommend provisions to address noise issues in early education as part of a major legislative review.

1.3 Thesis outline

The thesis is presented in the following 14 Chapters as follows:

1. **Introduction**: A brief discourse is given on the important issues of noise in early education with the research questions proposed and aims of the study presented. A glossary of terms is listed at the end of this chapter.

2. **Studies of noise and hearing loss in education - A literature review:** A comprehensive review of key literature is presented involving classroom noise, acoustic barriers to learning, speech interference in classrooms and children at risk. The key material from a New Zealand classroom study was outlined so that comparison could be made to this work. Finally, a range of available data was presented from the available New Zealand hearing screening statistics to evaluate the current status of hearing in young children and examine trends over the last few decades.

3. **Noise in New Zealand early childhood education centres - A pilot study:** This chapter reports on a short exploratory study of noise levels in selected early childhood centres to give an indication of the levels of noise in these centres and form the basis from which a comprehensive study could be planned.

4 **Speech intelligibility, processing and speech interference levels:** This chapter explains important relevant concepts such as speech intelligibility, the frequency analysis of the typical male and female voice under different vocal conditions and introduces important indices such as the articulation index (AI), speech transmission index (STI), and speech interference level (SIL).

5 **The anatomy and physiology of the auditory system and processes:** The anatomy and physiology of the human processes of hearing are discussed in detail.

Current knowledge of the composition of the cochlear inner ear fluids is presented along with the current knowledge on the activation of the cochlear hair cells to produce nerve energy. The neuro-auditory pathway and the development of the ear in gestation are also presented.

6 **Diseases, conditions and disorders giving rise to auditory function deficits:** A wide range of diseases and disorders affecting hearing and auditory function are presented and discussed. Assessment tools such as audiometry and tympanometry are explained. Diseases and conditions relating to hearing such as noise-induced hearing loss, and middle ear infections such as otitis media with effusion are explained, together with a wide range of disorders giving rise to auditory processing problems such as autistic spectrum disorders, central auditory processing disorders, attention deficit hyperactivity disorder, and developmental delay.

7 **Noise survey methodology:** This chapter presents the experimental investigations undertaken, the equipment/tools used, and the noise descriptors/criteria measured.

8 **Results of fixed time-average levels taken and personal sound exposure levels of children and staff**: This chapter reports on responses to a questionnaire and survey of teachers about the teaching aspects of their workplace and the specific issues of noise in their centres. In addition, affects of noise on at-risk children are reported as assessed by respondents such as teachers, professionals who work with these children, and parents. Information was obtained on the affects of noise on a wide range of children with disabilities such as sensory integration disorder (autistic spectrum disorder and a subset of giftedness), hearing impairment, central processing disorder, developmental delay, and attention-deficit/hyperactivity disorder etc. Deficiencies in the physical and acoustical environment necessary to meet the needs of these children were identified.

9 **Survey of early education staff and specialists:** This chapter reports on sound pressure levels measured in early childhood centres and includes time average levels taken by fixed sound level meters, personal sound exposures recorded by doseBadges fitted to the clothing of individual children, and personal sound exposures of staff. Special events and activities such as music sessions and walking excursions were monitored.

10 **Building and environmental inspection:** This chapter reports on survey work on the physical aspects of the premises and surrounding environment, which is likely to impact on the acoustic quality of the learning space, and noise intrusion from activities outside the premises. Acoustical properties of the learning spaces were measured by recording reverberation times. Several centres had acoustic wallboard and ceiling tiles retrofitted. Reverberation times were recorded before and after treatment and differences evaluated.

11 **Occupational hearing issues of staff:** This chapter reports on a small extension study carried out at the specific request of two large early childhood centres. Audiograms were taken of staff before and after work, along with personal sound exposures to assess the level of noise encountered and what affects this had on the temporary threshold shift at the end of the working day. As there was a good spread of age among participants from those in the early stage of their working life to those nearing retirement, the hearing status of staff in relation to their age was evaluated to see if any particular trend emerged.

12 **A new regulatory framework:** The current New Zealand legislation governing early childhood centres is undergoing a major review and early consultation with stakeholders revealed noise as a major issue, which has to be dealt with. Legal frameworks, which could be considered, are discussed and evaluated and the recommendations made are presented.

13 **Discussion:** The results of the full study are summarised and discussed. Pertinent findings are highlighted with recommendations suggested for further consideration.

14 **Appendices** Included are details of the ethics committee approvals to conduct the study, the development of a noise management plan, published papers directly attributed to this work, sample monitoring reports and the interview/survey sheets used.

1.4 Glossary

A

Acoustics: The science of sound including its production transmission, reception and effects.[12]

Acoustics of a room: Those characteristics that determine the room character in respect of human auditory perception. Reverberation time and the speech transmission index are two measures for determining the acoustical quality of a room.[12]

***All day centre*[*]: (**licensed under *Regulation 7, Education (Early Childhood Centres) Regulations 1988).* An early childhood centre permitted to operate where any child attends for a period of more than 4 hours on any day.

All practicable steps*∗: *(as defined by *Clause 2A, Health and Safety in Employment Act 1992)*. All steps to achieve the result that is reasonably practical to take in the circumstances, having regard to set criteria as specified in the Act which includes i.e. nature and severity of harm, current state of knowledge, cost, and means available to achieve the result.

Ambient sound/noise: The all-encompassing sound/noise associated with a given environment at a specified time. This is usually a composite sound including any sounds of interest.[12]

Anion: A negatively charged ion.

Articulation (intelligibility): The percentage of speech units correctly received by a listener out of those transmitted. 'Articulation' refers to units of speech material which are meaningless syllables or fragments. 'Intelligibility' is used to refer to units of speech, which are complete meaningful words, phrases or sentences.[12]

Articulation index: A number from 0-1, which is a measure of the intelligibility of speech.[12]

Audiogram: A standardized template or graph on which the hearing threshold of each ear is separately plotted as a function of frequency. Across the top horizontal axis the audible frequency bands are listed and on the left axis, Hearing threshold levels (in dB) descending in 10 dB increments are listed (-10 dB to 110 dB Hearing loss). The tracing is usually plotted by hand using the following convention:

- red circles joined by solid lines for the right ear
- black crosses joined by dashed line for the left ear

Audiometry: Pure tone audiometry is the measurement of the hearing threshold level of a person by a bilateral pure tone air conduction threshold test. The preferred method is

[*] *(in italics*) Denotes a legal term which has specific meaning in the legislation.

based on the technique developed by Carthart and Jerker and later modified by Hughson and Westlake.[15] The test is conducted by presenting a series of individual pure tones to the person (usually through headphones) in the audible frequency bands of 250, 500, 1000, 2,000, 4,000 and 8,000 Hz. Tones are presented by a standardized procedure to determine the hearing threshold level in the particular frequency band. The results are presented in an audiogram.

Auditory integration training (AIT): A form of sound stimulation claiming to desensitise individuals with sensory integration problems.

Attention-deficit/hyperactivity disorder (ADHD): A disorder characterised by over activity, impulsiveness and inattention although all may not be present.

Autistic spectrum disorder (ASD): A life long neurological and genetic disorder that causes deficits in the way information is processed.[13] ASD is continuum of disorders ranging from severe or classical autism, also known as Kanner's Syndrome, to the more able or high functioning autism and Asperger's syndrome.

A-frequency weighting: A network incorporated into a sound level meter to provide a simple measure of how loud a sound is perceived. A-frequency weighting has the response equal to the inverse of the equal loudness contour that passes through the 1000Hz at 30 dB. Other frequency weightings such as B and C were developed, but now by international consensus and standardisation, A-frequency weighting is the weighting almost exclusively used for sound level measurement.[14]

B

Background noise: The total noise from all sources other than a particular sound of interest or that under investigation.[12]

C

Cation: A positively charged ion.

Central auditory processing disorder: (CAPD): A deficiency in transmitting auditory impulses to the higher brain centre. CAPD describes a deficit in the entire analysis of auditory information due to a dysfunction of the central nervous system.[15]

D

Daily sound exposure: The amount of sound energy a person receives during a representative working day. It is the time integral of the squared instantaneous frequency weighted sound pressure over an 8-hour working day. The standard units are pascal squared seconds (Pa^2s) but in industry it is more convenient to use pascal squared hours (Pa^2h).[12,16]

decibel or deciBel (dB): a term used to identify 10 times the logarithm to the base 10 of the ratio to two like quantities proportional to intensity, power or energy.[17]

Dyspraxia: a neurological disorder involving difficulty in planning, sequencing, and carrying unfamiliar actions in a skilful manner.[18]

Dose: the amount of noise exposure relative to the exposure limit for a working day and is stated as a percentage of the limit.[22] In New Zealand, a noise dose of 100% is equivalent to 1 pascal squared hour or an A-frequency weighted time-average level of 85 dB over an 8-hour working day ($L_{\mathrm{Aeq\ 8h}}$ = 85 dB).

E

Early intervention: Treatment or therapy given to young children usually in their preschool and early years of school to prevent or mitigate problems as well as to enhance the child's health and development.[18] Speech language therapy, music therapy and occupational therapy are common therapies provided in New Zealand for speech, communication and developmental problems.

F

Frequency: A measure in Hertz (Hz) of the repetition rates of components of an acoustic oscillation expressing the number of cycles per second.[12]

G

Gestalt perception: A difficulty to distinguish between foreground and background information.[19]

I

Inclusive education: UNESCO[20] defines inclusive education as "A developmental approach to the learning needs of all children, youth and adults, especially those who are vulnerable to marginalization and exclusion. The principle of inclusive education was adopted at the World Conference on Special Needs Education: Access and Quality (Salamanca, Spain, 1994), restated at the World Education Forum (Dakar, Senegal, 2000) and is supported by the UN Standard Rules on the Equalization of Opportunities for Persons with Disabilities."

I-INCE: The International Institute of Noise Control Engineering

Integrating-averaging sound level meter: An instrument that is used for measuring sound pressure level with standard frequency weighting components and a standard time averaging facility. These instruments are able to log, integrate and process data collected over a specified time period(s) to give values for a sweep of standardised sound descriptors such as time-average level, peak level, maximum sound pressure level (in some instruments exceedance levels and sound exposure levels depending on usage) for the period sampled. In addition to giving numerical values for these parameters, many modern meters are produced with accompanying software to allow data to be downloaded to a PC for further processing and production of graphics such as time histories.

Intelligibility: See ‘Articulation’

Italics: Words and phrases presented in italics (except in the References) denote legal terms or definitions, which have specific meanings in the legislation. In addition, the legal title of legislation is presented in italics. For example: *Education (Early Childhood Centres) Regulations 1998.*

L

Language deficiency (receptive aphasia): A deficiency in the interpretation of auditory impulses after they have been transmitted.[12]

Lombard effect: The automatic raising of one’s voice when speaking in a noisy environment. Also known as the “Café effect”.

M

Maximum A-frequency weighted sound pressure level (L_{Amax}): This is 10 times the logarithm to the base 10 of the square of the ratio of the maximum sound pressure, to the reference value 20μPa. This is an RMS value and must not be confused with the peak level (L_{peak}), a non-RMS value.

Minimum audible field (MAF) Threshold: The sound pressure at threshold of hearing for young adults with normal hearing.[21]

N

New Zealand Disability Strategy 2001: A formal policy document adopted by the New Zealand government which presents a long-term plan for changing New Zealand from a “disabling” to an “inclusive” society. The strategy has adopted wide reaching actions and objectives in ensuring rights, the provision of the best education, the advancement of employment opportunities, the provision of support systems etc, and to enable the disabled to lead full and active lives.

Noise: (1) Any disagreeable or undesired sound or other disturbance. It may also include any unwanted disturbance within a useful frequency band such as undesirable electric waves in a transmission channel.[12]
(2) Sound of a general random nature. The spectrum does not show any defined frequency components.[12]

Noise - induced hearing loss (NIHL): A sensorineural hearing loss resulting from excessive exposure to noise usually over periods of time. It is characterised initially by loss in the frequency range 4,000-6,000Hz. This form of hearing loss is usually permanent.[12,22,23]

Noise reduction coefficient (NRC): An index of the ability of a material to absorb sound. This is calculated by averaging the sound absorption coefficients at the frequencies 250, 500, 1000, and 2000 Hz.[24]

***Notifiable* or *Notified consent**:** The public notification of a consent application (under the *Resource Management 1991*) to invite public submissions to be considered as part of the approval process.

O

Occupational therapy: An allied health profession that helps people improve the functioning of their nervous system in order to develop skills leading to independence in personal, social academic and vocational pursuits.[18]

Octave bands: The division of the audible frequency range into a standardized series of adjacent frequency bands where the upper frequency is twice the lower frequency. Each of these bands can be further divided into one-third octave band frequencies.

Osmolarity: The concentration of osmotically active particles in solution, which may be quantitatively expressed in osmoles of solute per litre of solution.[25]

Osmole: A unit of osmotic pressure equal to the molecular weight of solute expressed in grams divided by the number of ions or other particles into which it dissociates in solution.[26]

Otitis media with effusion (OME): An inflammation of the middle ear in which a collection of fluid is present in the middle ear space.[27]

P

Peak level (L_{peak}): The peak level, expressed in decibels, is 10 times the logarithm, to base 10 of the square of the ratio of the peak sound pressure to the reference value 20μPa.[12] It is a non-RMS value and should not be confused with L_{Amax}. It has no frequency weighting, but to limit the measurement to sound in the audio-frequency range, a “Z” weighting is used to provide a cut off at high and at low frequencies. A “C’weighting is often used if no “Z” weighting is provided on the sound level meter and is stipulated in some standards. In New Zealand it is measured according to NZS 6801:1999 Acoustics –the measurement of sound.

Perilymph: The fluid between the bony and membranous labyrinths of the ear.[26]

Pervasive developmental disability: Severe overall impairment in the ability to regulate sensory experiences, affecting the child’s behaviour, interaction with others and communication skills.[18]

Presbyacusis: The sensorineural hearing deterioration associated with age.[23]

Public Health Commission: The Public Health Commission was established as a government body, independent of the Ministry of Health, by the New Zealand Government in the early 1990s, as a result of the major health reforms carried out at the time. Key functions included direct advice to the Minister of Health on improving and

* *(in italics*) denotes a legal term which has specific meaning in the legislation

protecting the public health of New Zealanders, and to ensure that government funds dedicated for public health were used appropriately. The Commission was disestablished in 1996 and the functions transferred to the Ministry of Health.

R

Reverberation: Sound that persists in an enclosed space, as a result of repeated reflection or scattering after the sound source has been stopped

Reverberation time (T_{60}) or (RT 60)of an enclosure: The time (expressed in seconds) that is required for a sound pressure level of a given frequency or frequency band to drop 60 dB in any enclosure after the source of the sound has stopped.[28]

RMS: Root mean square

S

Sensory diet: (1) the multi-sensory experiences that one normally seeks on a daily basis to satisfy one's sensory appetite. It is not just related to sensory experiences with food. (2) a planned and detailed activity programme developed by an occupational therapist to assist the self regulation of an individual. A sensory diet is a tool often prescribed for individuals experiencing sensory integration disorder.

Sensory integration disorder: The inefficient neurological processing of information received through the senses, causing problems with learning, development and behaviour. (Also known as 'sensory integrative dysfunction', or 'sensory modulated dysfunction').[18]

***Sessional* centre[*]:** (licensed under *Regulation 7, Education (Early Childhood Centres) Regulations 1988*). An early childhood centre permitted to operate only where no child attends for a period of more than 4 hours on any day.

Signal-to-noise ratio (SNR): The signal level minus the noise level (dB).[12]

Sound exposure: The time integral of the squared instantaneous frequency weighted sound pressure over a specified time interval or event. The standard units are in pascal squared seconds (Pa^2s) but can also be quoted in pascal squared hours (Pa^2h).[12]

Sound level meter: an instrument for the measurement of sound pressure level that complies with either or both IEC 60651 or IEC 61672.[12]

Sound pressure level (L_P): expressed in decibels is ten times the logarithm of the square of the ratio of the frequency weighted and time weighted sound pressure level to the reference value 20 μPa. The formula is given below:[17]

[*] (*in italics*) denotes a legal term which has specific meaning in the legislation.

$$L_P = 10 \log \left[\frac{p}{p_O} \right]^2 dB$$

Where:

p is the rms sound pressure in Pa
p_O is the reference value of 20 μPa

Special education: Individualised instruction and planning for children with special needs or learning difficulties in education - especially in school and pre-school.

Speech language therapy: Treatment to help a person develop or improve articulation, communication skills and oral motor skills.

Speech transmission index (STI): Index for rating the intelligibility of speech that takes both noise and reverberation into account.[12]

T

Threshold of hearing: This is the minimum sound pressure level for a specific sound that can evoke an auditory response.[12]

Time-average level ($L_{Aeq\ t}$): the value of the A-frequency weighted sound pressure level of a continuous steady sound that, within a measurement sample time (t) has the same mean square sound pressure as the sound under investigation whose level varies with time. The time period for every L_{Aeq} measurement should be stated. The formula is given below:[17]

$$L_{Aeq,t} = 10 \log \left[\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} \frac{p_A{}^2(t)}{p_O} dt \right]$$

Where:

$p_A(t)$ is the instantaneous A-frequency –weighted sound pressure level
p_O is the reference value of 20 μPa
t_2-t_1 is the measurement sample time period in seconds

Temporary threshold shift (TTS): The temporary raising of the hearing threshold level after exposure to loud sound.

Threshold of pain: The minimum sound pressure level of a specified sound, which will give a definite sensation of pain (for a given individual).

Tympanometry: A technique designed to measure the response of the middle ear to sound energy and provides quantitative information on the function and presence of fluid in the middle ear.[29]

W

Weighting: This refers to the effect on a signal of electronic circuits that modify the signal in a standardised manner. Frequency weighting refers to modifiers of frequency response. Time weighting refers to modifiers of the integration time.

WHO: The World Health Organization

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2 Studies of noise and hearing loss in education - A literature review

2.1 Introduction

Despite considerable searching of available databases and personal contact with experts worldwide on this topic, it appears that very little work has been carried out on noise in early education. Information to date reveals that this work is likely to be the first study of its kind internationally to investigate noise levels in this educational sector. This is surprising as the preschool years are critical to language development in children, and are very high-risk times for otitis media infections with effusions. Poor acoustical environments in preschools are likely to have significant detrimental effects on learning at preschool level and later on in school.

There is an increasing level of awareness of noise in schoolrooms and the effects that this is having on children's ability to learn, their development and behaviour. Studies are now beginning to address the issues of children with auditory function disorders and how these are affected by noise in formal school learning situations. In 2000, a number of papers were published in the clinical forum of 'Language, Speech and Hearing Services in Schools' (a journal published by the American Speech Language Hearing Association). Included in this literature were papers on relevant legislation (USA),[1] acoustical barriers to learning and at-risk children,[2] children with normal hearing and hearing impairment,[3] intervention technology[4] and methods to provide a high quality acoustical environment.[5] Included in New Zealand literature are studies by Bennetts and Flynn,[6] Blake and Busby[7] and Wilson et al.[8]

Hearing specialists, and probably other professionals dealing with special needs children who are profoundly affected by noise, have long requested that acoustics be considered in the design of classrooms and learning spaces, but this issue up to the present time has received little attention.[1] The *Americans with Disabilities Act,* passed by the US Congress in 1990, has been described by Sorkin[1] as a landmark piece of legislation, requiring new and innovative structures to meet specific accessibility guidelines for people with disabilities. While specialists dealing with hearing and auditory processing disorders have long recognised the importance of the acoustical environment for children with auditory problems, few legal mechanisms are available at school to secure this important accommodation for their special needs children.[1] In an informal survey of parents conducted in North America by Sorkin[1], it was reported that few personnel at the schools were willing to include acoustics as part of their child's individual education plan (IEP).[*] Sorkin emphasised that the IEP process should allow for consideration and inclusion of acoustical improvements to existing learning spaces, but in reality few parents have been successful in their efforts to gain improvements. From comments received from respondents, Sorkin reported that there were serious problems in schools with background noise and reverberant surfaces. Many of the respondents described a wide range of special populations that may benefit, which included not only the hearing impaired, but also those children with central auditory processing disorders (CAPD), and attention-deficit/hyperactivity disorder (ADHD). This work identified a major at-risk group, not highlighted in most other publications, as those on the autistic spectrum and a subset of gifted children, both of which experience sensory integration disorder. (See Chapters 6 and 9)

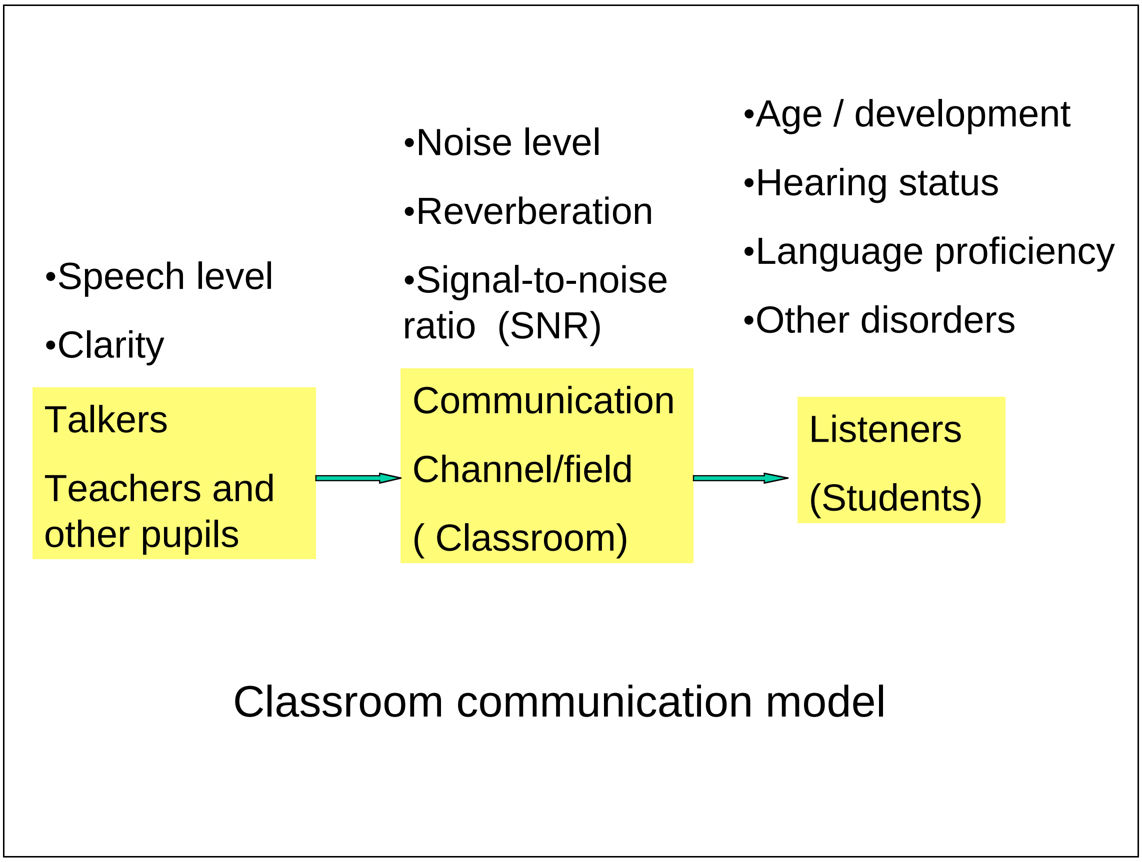
A number of authors including Sorkin,[1] Nelson and Solti,[2] and Solti and Sullivan[9] state that younger children (generally before their teenage years) are immature listeners. Hearing and noise tests carried out with children have found that children's ability to understand sentences in noise improves through the early childhood years, which reaches the adult level in the teenage years. Nelson and Solti concluded that young children need a good acoustical environment for full understanding. Likewise they are at risk of impaired learning in a noisy or reverberant environment. Sorkin concluded that the entire population (with or without disabilities) would benefit from improved acoustics in their learning environments.

Nelson and Solti[2] proposed a model of classroom (verbal) communication where they presented the interlinking factors or parameters influencing effective communication

[*] An individual education plan (IEP) process is a system used widely for special needs children unable to meet the normal curriculum level. It involves the setting and review of an individual plan of education for the child with the school teachers, education support workers, education specialists assigned to the child, and the parents.

(see Figure 2-1). As verbal communication begins with the speaker, the speaker's voice must be at sufficient levels to be received and processed. In the 'field' or 'communication channel' (the space between the speaker and listener), the background noise level, reverberation time and the signal-to-noise ratio are all critical factors, which will affect the listener's ability to receive and comprehend the spoken word. Excessive reverberation and background noise may play an important role in this channel of masking and/or degrading speech perception. Finally the age and/or development of the listener(s), their hearing and auditory processing status, their proficiency in the language spoken, and any deficits in development or auditory processing ability can have a major impact on the listener's ability to comprehend speech. Children with typical hearing and development may be able to understand speech under certain conditions, whereas those in the same classroom or learning space with hearing impairment, auditory processing deficits or who are second language speakers, may not be able to comprehend the same spoken word in identical conditions.

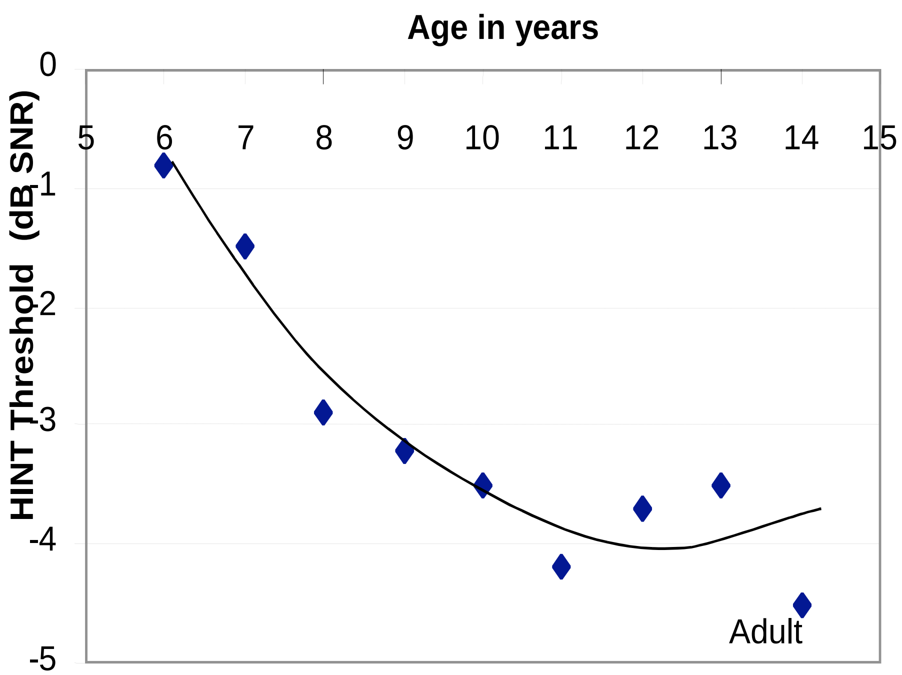
Figure 2-1 Model of classroom communication



Source: Nelson and Solti[2]

Nelson and Solti have graphically presented the mean improvement in the 'hearing in noise test' (HINT) threshold, in relation to age groups of normal development of children, as shown in Figure 2-2 (below).[2] (**SNR** = Speech-to-noise ratio).

Figure 2-2 Developmental aspects of hearing in noise



Source: Nelson and Solti[2]

Nelson and Solti[2] presented a study by Solti and Sullivan[9] using the Hearing In Noise Test HINT developed by Nilsson, Solti and Sullivan.[10] They also cited a number of other studies with similar findings and indicated that there was overwhelming evidence to suggest that young children are less sophisticated learners than are older children and adults. They concluded that young children can be expected to require more favourable learning environments and therefore are at-risk of reduced learning capacity in noisy or reverberant conditions.

2.2 At-risk children and important acoustic conditions

Nelson and Solti[2] list the following groups of at-risk children. These are children who have a disability, impairment or impediment which compromises their ability to learn to the same extent as their peers, particularly when placed in unfavourable physical, environmental or social learning conditions.

2.2.1 Second language speakers

As the ability to understand the language spoken is related to the proficiency and experience with the language, second language speakers performed more poorly than their peers who were native speakers. Children, who are less experienced in the language of instruction, require more favourable conditions for understanding classroom conversations.

2.2.2 Children with hearing loss

This group of children are at great risk for the detrimental effects of poor classroom acoustics. The USA, like New Zealand, has a high incidence of otitis media with effusion (glue ear). The authors have cited studies, which have found a large number of children with slight or mild hearing loss in parts of the USA who, while unaware of their loss, showed significant dysfunction when compared to their peers with normal hearing and auditory function. Other studies cited by Nelson and Solti[2] have found major educational consequences with incidence of minimal hearing loss. This is supported by Allen[11] in New Zealand, who reported on a large study in Dunedin, where just over 1000 children were enrolled in a multi-disciplinary study with regular follow-up until 15 years of age. A group of these children who had otitis media in both ears were found to be significantly behind the children with normal hearing at age 3 years. Allen suggested that this condition had been present for sometime and that significant harm had already been done by that age. Despite receiving treatment at age 5 with antibiotics or insertion of ventilation tubes, this group by the time they were 15 years old, were on average 2 years behind their peers with normal hearing in their reading ability. This significant difference means these children will have a lower chance of passing school examinations along with reduced chances of employment. Allen[11] also indicated a strong association in this group with otitis media with effusion and later development of eardrum abnormalities.

Classrooms have been described as active and noisy places. Increased noise is a consequence of the recent trends in education which often involve collaborative interaction of multiple minds and tools as much as individual possession of information.[2,12] Nelson and Solti[2] suggest that background noise levels of most unoccupied classrooms are too high for maximum understanding by all students. They found only one in eight of these classrooms had A-frequency weighted background sound levels below the 30 dB level recommended by the American Speech Language Hearing Association, which is identical to that recommended by the World Health Organization.[13]

2.2.3 Reverberation time and effects

Reverberation time is an important physical acoustical characteristic and can degrade speech perception in the classroom by smearing or masking the temporal properties of speech signals, making them more difficult to understand.[2,3] Like noise, reverberation tends to degrade the perception of the softer consonant sounds. In highly reverberant spaces, where there is an audible echo, words may overlap and the reverberant sound energy fills temporal pauses between words.[3]

Crandell and Smaldino[3] suggested that the combination of noise and reverberation combine synergistically to affect speech perception. This means that if either noise or reverberation was present, speech perception could be degraded by 10%, but if both noise and reverberation quantities were present in the same room, the combined degradation of speech perception could equate to 40%-50%. They indicated that such synergistic effects appear, because the reflections, which fill temporal gaps in the noise, make it into a more steady state in nature, and therefore the information in those gaps is no longer available for the ear to discern.[3]

2.2.4 Dealing with background noise

Background noise, as described by Crandell and Smaldino,[3] refers to any undesirable auditory stimuli that hinders or obscures the audio information a child wants or needs to understand in a classroom setting. This, of course, includes noise generated externally intruding into the classroom or learning space. It can include transport, aircraft, road works and where mechanical heaters or ventilation systems are installed. Background noise often varies considerably depending on the time of the day. Many studies have reported background noise as measured by single number descriptors such as an A – frequency weighted time-average level (L_{Aeq}). There is difficulty in obtaining this acoustic descriptor at the important time (i.e. when the children are normally present). At times when children are not present, such as school holidays and weekends, the background noise levels can be very different due to different traffic flow etc. However these authors[3] suggest a more thorough procedure for background noise assessment is via the use of noise criteria (NC) curves developed by Beranek,[14] where a spectral analysis in octave bands or preferably one-third octave bands is conducted across the eight standardized frequencies between 125Hz to 8000Hz.[3] This method has the distinct advantage of a broadband time-average level by isolating the low frequency noise present. This is, perhaps, of greater importance, when central heating or air conditioning systems are in use. Most New Zealand early childhood centres and schools do not have central heating or air conditioning systems, but a number have fan type heaters where hot air generated by the unit is circulated by a mechanical fan. Wilson et al[8] chose to use C-weighting for time-average level measurements to evaluate low frequency noise. This is discussed in more detail in Section 2.5 ‘Background to the New Zealand situation’ (on page 2-16).

Crandel and Smaldino[3] state that the masking effect of background noise interferes with the child’s ability to perceive speech by masking the acoustic and linguistic cues that are available in the teacher’s spoken word. In particular, background noise has the greatest impact on consonant perception because the spectral energy of consonants is less intensive than that of the vowels. They find that minimal decreases in consonant perception can significantly influence speech perception because consonantal energy is a critical factor in the listener’s ability to understand speech.[3]

The most significant maskers for speech are invariably noises with long-term spectra similar to the speech spectrum, because all speech frequencies are affected to the same degree. Therefore typical classroom chatter generally produces the greatest effect on speech perception because the teacher's voice has a similar spectrum.[3] As noise generally produces more effective masking for speech of a higher frequency (described as an upward spread of masking), low frequency noises (e.g. air conditioning units and similar type machine noise) tend to produce the higher levels of masking. Continuous noises (hums etc from fans, fluorescent lighting and chatter) are generally more significant maskers than impulse or interrupted noise.[3]

2.2.5 Distance from speaker to listener.

Distance is an important factor in influencing speech perception. At close distances the teacher's voice predominates in this sound-field with minimal interference from other acoustic factors such as background noise and reverberation from room surfaces.[3] Generally the sound decreases by 6 dB for doubling of the distance (inverse square law). This law more often applies outdoors but inside rooms the reverberant field increasingly plays a part with increased distance.[3] An indirect sound-field (not directly from the speaker) originates at a critical distance, which is defined as:[3]

$$D_c = 0.2\sqrt{VQ/nRT}$$

where:

D_c	=	critical distance for start of indirect sound field.
V	=	volume of room (m^3)
Q	=	Directivity factor of the source (human voice generally a value of 2.5)
n	=	number of sources
RT	=	Reverberation time of enclosure at 1400 Hz.

The distance a child is from the teacher can have a major effect, as beyond the critical distance, the indirect sound-field can significantly reduce speech perception.[3]

2.2.6 Studies on effects of noise on children and their teachers

Maxwell and Evans[15] undertook a study on the effects of noise on preschool children's pre-reading skills. This is a particularly important study, as few studies on such young children exist. Ninety children participated over a 2-year period. Tests were conducted in a childcare centre with poor acoustics before and after the modifications were carried out to improve this aspect of the learning environment. The authors took time-average levels over a 4-hour period for similar activities before and repeated after renovation.

Children were found to perform better in quieter conditions on cognitive measures and to answer more questions correctly on the measure of pre-reading skills. Children in the quieter conditions were rated by their teachers on the language scale as using the understanding language to a higher degree than their peers in noisier environments. These children in quieter rooms solved puzzles significantly faster than their peers in the noisier rooms. The authors concluded that chronic exposure to high noise levels affects preschool children's language and pre-reading skills.

It is unclear whether monitoring was done over multiple sessions and the result averaged or if monitoring in each case was a single event. As sound pressure levels can vary from day to day, how such confounding factors were addressed is not clear in the report. It would usually be necessary to monitor several sessions before and after the modifications to the room as there are a number of confounding factors which cause time-average levels to vary considerably as a function of time (as indicated by Crandel and Smaldino[3]) and from day to day. These include such factors as numbers of children present, activities undertaken and inclement weather, which keeps children indoors. In addition, peak levels (L_{peak}) were used as a measure of acoustical characteristics. Peak level measurements are not RMS values but a measure of the over-pressure of short instantaneous events of sound such as sharp impact type events as a door slamming or the striking an object with a hammer etc. This descriptor would depend on the frequency and intensity of such events and it is difficult to see how this can be related to building characteristics. For example, peak levels will be influenced by how hard and how often a door is slammed. Reverberation time is a more effective descriptor to compare the acoustical properties of the room before and after renovation and could have been used in this case. The nature of the renovations carried out was not discussed in detail. The authors described the preschools room with a ceiling higher than 12 feet (3.6 metres) and some walls not of full height partitions. However from photographs in the report, the room appears to be an open plan type room with open trusses and the ceiling following the roof line. The modifications appeared to be largely an installation of sound absorbent panels hanging from the roof trusses. Semi-height partitions may have been extended to full height partitions but whether any other modifications were made (e.g. to the wall surfaces) is unknown. It would have been helpful for considerably more detail on the original room characteristics and then to present in detail what modifications were made. It would have also been helpful to give the specifications of any acoustic material fitted, or at least information given on where this can be obtained.

Due to other fundamental errors in this report, the reliability of the acoustics section is questionable. The authors referring to a ‘sound level meter’ as a ‘decibel meter’ and time- average level (Leq) as "Leg" are two fundamental errors which bring into question the competency of the authors in acoustical techniques and the peer-review process of this section. Confusion between the RMS maximum sound pressure levels and the non-RMS peak levels cannot be discounted. From the data presented, it does seem that the renovations resulted in significant improvements to the learning of young children.

A comprehensive study by Enmarker and Bowman[16] examined the responses to annoyance of teachers and their pupils. There were 207 responses from pupils aged 13-14 years and 166 responses from teachers aged 21-65 years. Models that fitted both pupils and teachers were tested. The majority of participants perceived activity noise such as classroom chatter, and furniture scrape as the most disturbing noise sources with the rating for teachers significantly higher than those from the pupils. On the self-evaluation of their health, teachers rated themselves as more adversely affected than pupils with more frequent sleeping problems, tinnitus, tension and fatigue after work. Pupils rated themselves as more irritable. Teachers experienced the noise as less predictable compared to the pupils. The authors suggested that the ability to predict noise is of more importance and that unpredictable noise may cause a higher degree of annoyance of teachers. This could reflect that teachers are more sensitive to information overload. Findings over gender difference were inconsistent.[16]

Haines et al[17] investigated the effects of chronic aircraft noise on mental health and cognitive performance in 340 children aged 8-11 years attending schools in areas of high aircraft noise and compared these to children in matched controlled schools with lower levels of noise. They found that chronic aircraft noise exposure resulted in higher levels of annoyance and poorer reading comprehension using standardized scales where adjustments were made for age, deprivation and language spoken. However they found that chronic exposure to aircraft noise was not associated with mental health problems e.g. (anxiety, hyperactivity, behaviour etc) in children.[17]

Classroom noise is an occupational concern for teachers particularly as they are exposed to this throughout their working life. An interesting study by Grebennikov[18] in Sydney, Australia investigated the effects on 25 preschool staff in 14 early education settings. Noise dose exposure was assessed by fitting doseBadges identical to those used in this work. Of the 25 teachers, the four highest individual A-frequency weighted time-average ranged from 85-86 dB during contact hours but reduced slightly with a correction to 8 hours due to the non-contact working hours. Australia and New Zealand use the same noise exposure criteria. Personal exposures of these teachers ranged from 70-103% dose, with one exceeding the maximum permissible level of 100% dose. Nine staff members recorded peak levels (L_{peak}) exceeding the permissible levels of 140 dB. High levels of noise were found from the following activities:

- Inclement weather confining students indoors
- Insufficient space (confined indoor area)
- A resonant floor, furniture and / or play equipment
- Distressed students
- Those students who are over exuberant
- Noisy indoor activities (assemblies, music, bells)
- Air conditioning
- Alarms

Oberdorster and Tiesler [19] found that room acoustics had a major effect on the A-frequency weighted time-average levels ($L_{\text{Aeq t}}$) in teaching spaces. The shorter the reverberation time (T_{60}), the greater the speech intelligibility. They established a near linear relationship with a decrease of 2 dB in sound pressure levels per 0.1-second reduction in reverberation times between reverberation times of 0.3-0.8 seconds.

Oberdorster and Tiesler[19] suggest that stress (which they measured by monitoring individual heart rates) in teaching is dependent on the ergonomic factor of room acoustics and claim to have established a clear relationship between stress responses and noise in teaching. They found that if the A-frequency time-average levels over the period in teaching falls due to improved room acoustics, the stress state of teaching staff is simultaneously reduced. This was demonstrated by the heart rate of a teacher reducing by 10 beats per minute when she was teaching in a quieter lesson (less 5 dB). All other confounding factors, which could give rise to the same response, were accounted for as far as could be monitored in a field investigation.

Finally, these authors found that noise did have a major effect, not only in regard to heart rate, but changes in sensitivity to noise. Under improved acoustic conditions, the impact of noise was to have a less stressful effect with far less elevation in heart rate. The reduced noise was not the causal factor, but the resultant improved speech intelligibility and communication conditions.[19]

2.2.7 Classroom Amplification

A number of reports have shown that some classroom characteristics produce barriers in listening and learning to at-risk children. Smaldino and Crandell [4] state the following reasons why classroom acoustics are important:

1. Classrooms are auditory verbal environments that require accurate reception of verbal speech signals from the teachers or pupils.
2. Excessive background noise can mask key elements of speech and render it less identifiable.
3. Reflected sound in a classroom (reverberation) can both mask speech and smear important temporal cues that are necessary for accurate speech and language perception.
4. Excessive noise, reverberation, and loss of speech energy over distance occurring simultaneously result in synergistic effects in that they impact on speech perception to a greater extent than when any one of the these characteristic are considered separately.
5. The provision of early intervention, especially for children who have hearing impairment or speech and language problems, improves the possibility of

normal auditory-verbal development. This appears to lessen, the longer early intervention is delayed.

Hearing aids have a serious limitation in that they cannot distinguish the speech signal when there is competing noise or when the listener cannot be close to the speaker. In the classroom, an enhanced signal-to-noise ratio (SNR) is required to deliver a clear complete speech signal, which is essential for oral expressive language and reading skills.[20]

Individual and sound-field FM systems are 2 types of devices now in common use to enhance the SNR. Both use a remote microphone attached to a headset worn by the speaker (usually the teacher) and the signal is transmitted to the unit by radio waves. In individual units, it is the child who wears an FM receiver. In sound-field systems the sound is distributed to a class from a series of high quality speakers placed strategically in the room to maximise the benefit to all students. Both individual and sound-field systems improve the signal to noise ratio around the room.[4,20]

Flexer[20] and Palmer[21] suggest that all children could benefit from a sound-field system because the improved SNR creates a more favourable learning environment. There is ample evidence in literature to highlight the benefits of these systems. Canning[22] found that passages spoken through an FM sound-field system were understood better than comparable non-amplified passages. Bennetts and Flynn[6] investigated the use of sound-field systems with children experiencing Down syndrome. They found that despite the limited number of subjects, a sound-field system was of benefit to this group of special needs children. Their subjects only had mild hearing loss (middle ear infections are prevalent in this group) and for more severe cases they indicated that the benefits would be greater.

In a particularly relevant study by Palmer,[23] a sound-field system was experimentally controlled in a study carried out in a kindergarten. When the sound-field was in use, there was a marked decrease in the level of inappropriate student behaviour but when the system was turned off, a significant increase in inappropriate behaviour occurred.

The students also demonstrated a marked increase in appropriate task management immediately following the use of a sound-field system.

In the 'Guidelines for classroom acoustics in new construction'(USA),[24] the authors point out that sound-field amplification systems will add background noise in work areas within the room and can intrude into adjacent spaces without adequate acoustic insulation. As the typical system uses a microphone it may not be ideal in group learning situations. These devices enhance the speech signal but will not compensate for poor classroom acoustics. Control of reverberation and background noise is also essential for amplification to be effective. It has to be remembered that amplified background noise can be very painful and disruptive for children with auditory disabilities such as those with sensory integration problems.[24] This is very much the case with children experiencing sensory integration disorder such as those on the autistic spectrum.

2.3 Guidelines for community noise - World Health Organization

The World Health Organiszation[13] has published its 'Guidelines for community noise', which have covered extensively, the wide ranging adverse effects of noise, including hearing impairment, interference with speech communication, sleep disturbance, cardiovascular and physiological effects, mental health effects, effects on performance, effects on residential behaviour and annoyance, effects of combined sources and vulnerable groups. The WHO suggests from evidence collected from animal experiments that children may be more vulnerable to acquiring noise-induced hearing loss than the adult population. This is difficult to quantify due to individual susceptibilities and cultural/ethnic factors through the populations of the World. From the limited data available, the WHO suggests that occupational hearing loss at A-frequency weighted time-average levels of 75 dB or less over an 8-hour day ($L_{\text{Aeq 8h}} \leq$ 75 dB) is unlikely to cause any hearing impairment even over prolonged exposure. In the absence of other data this is particularly important for children. Taking into account total noise exposure (including environmental and leisure time) over 24 hours/day, the

WHO finds that A-frequency weighted time-average levels of less than 70 dB ($L_{Aeq\ 24h}$ <70 dB) would not cause hearing impairment in a large majority of people (over 95%). The WHO suggests that the calculation method from ISO 1999[25] for specifying hearing impairment should be accepted for environmental and leisure time noise. As large-scale epidemiological studies are not available to support this proposition, the WHO advises care with respect to the following aspects for children:

- Children may be more vulnerable in acquiring noise-induced hearing loss than adults.
- The peak level exposure to which children are subjected should never exceed 120 dB as noise from activities such as fireworks and playing with noisy toys can potentially reach such levels. Some audiologists and hearing specialists recommend a lower figure of no more than 100 dB.[26]

Sleep disturbance is an issue in New Zealand *all day* centres, which are required by the *Education (Early Childhood Centres) Regulations 1998* to provide areas for sleep. It is important that children requiring sleep have appropriate quiet sleeping spaces and are not disturbed by other activities inside or outside the centre. The WHO recommends that indoor sound pressure levels should not exceed an A-frequency weighted time-average level of 30 dB ($L_{Aeq} \leq 30$ dB) for continuous noise. For non-continuous noise, an A-frequency weighted maximum sound pressure level (L_{Amax}) of 45 dB should not be exceeded more than 15 times during the sleep period. This was based on a study by Vallet & Vernet[27] on night time aircraft noise and sleep disturbance where they found tolerance to noise passes through a maximum value for an optimum value of 10-15 flights per night. With sensitive individuals a lower level is preferred. Vallet and Vernet recommended that the A-frequency weighted maximum sound pressure levels (L_{Amax}) should not exceed 48 dB when measured inside dwellings. This level would be difficult to achieve in sleep rooms of early childhood centres. More work is needed to determine appropriate noise levels and the types of sounds most disturbing to the sleep of babies and young children in daytime childcare facilities.

The WHO has identified children as vulnerable to the adverse effects of noise and cited studies by Cohen et al[28] and Evans et al[29] as providing enough compelling evidence to warrant monitoring programmes at schools and preschools. It is necessary to protect children from the effects of noise including those on speech perception and reading acquisition.[13]

2.4 I-INCE Technical Initiative #4.

In December 1999, the general assembly of the International Institute of Noise Control Engineers, (I-INCE), developed the Technical Initiative #4-'Noise and reverberation in school rooms'.[30 ,31] A technical study group was formed from members of I-INCE member societies TSG#4, which has been a major thrust in further studies and increased awareness of this issue. Vallet and Karabiber[32] prepared a preparatory document on European policies regarding acoustical comfort in educational settings to support the Technical Iniatiave #4. Annual conferences of the I-INCE now include forums on classroom acoustics and noise in education. Reporting on Technical Initiative #4 is now due.

The I-INCE Technical Initiative #4 recognised good acoustical environments as being central to learning in classrooms and therefore vital in every knowledge-based economy. Karabiber et al[4] reported that the main objective of this technical initiative, was to develop recommendations for schoolroom acoustical criteria, including practical knowledge of the costs and benefits of noise and reverberation control. This was to optimise the acoustical environment in learning spaces. The aims of these recommendations were to provide acoustical and noise control guidance to educational space designers and those who set standards and codes of practice for schoolroom design. The Institute noted that at that time, some countries including the UK, Portugal, and Sweden had already taken steps to establish standards and guidelines for schoolroom acoustics. The initiative would also provide support for countries where comprehensive standards and guidelines did not exist.

This technical initiative needs to promote dialogue and cooperation between those designing classrooms and those delivering education in them. It is particularly important for those designing or advising on appropriate acoustic criteria, to be aware of the needs of the students in the classroom and to cater for the most vulnerable in the design stages. The worldwide trend to mainstream special needs children with targeted education support, means that children adversely affected by noise will be present in many classrooms.

2.5 Background to the New Zealand situation

A number of studies indicate that much of what is learnt in the typical classroom occurs through the auditory channel i.e. by speaking and listening.[8,33] Wilson et al[8] state that optimum acoustics for ease of listening and good intelligibility are essential as school children spend up to 5 hours per week day in classrooms. In addition, because children's auditory and neurological systems are not fully developed until they are about 16 years of age, they lack experience to predict from context and have to learn to distinguish the important sounds such as the teacher's voice from background noise.[8]

In New Zealand, it seems that very little thought has been given to the acoustical design of classrooms in the past. This is probably due to the lack of legislation, standards and guidelines, as well as an expectation that noise in classrooms was an inevitable consequence of modern teaching practices.

2.5.1 Classroom acoustics study

One of the most extensive studies to be completed in New Zealand on classroom acoustics was carried out by Wilson et al[8] with sponsorship from the Oticon Foundation. This study was conducted among schools in the Auckland region, which were chosen across the socio-economic spectrum and each school had a small number of hearing impaired students wearing hearing aids. Approximately 120 teachers were surveyed with questionnaires. Classroom buildings were examined for construction details and internal finishings. Speech perceptions tests were carried out with children having normal hearing and those with hearing aids in occupied classrooms with background sound pressure levels recorded. Reverberation times were recorded along with noise levels over full school days. Acoustic modifications were made to some rooms to improve the acoustic environment and then the tests were carried out to monitor any changes and improvements. The authors of this study chose to assess background sound pressure levels as C-weighted time-average levels. This was carried out to address a concept known as ‘upward spread of masking’ where the loud low frequency noise masks the quiet high frequency sounds in speech. The authors claimed that this allowed them to consider the effects of low frequency noise on speech intelligibility. While this is an interesting concept, the authors could have given background sound pressure levels in both A and C weightings. This would allow more valid comparisons to be made with other studies using A-weighted sound pressure level recordings. A comparison of A and C weighted processing of the same sound pressure levels, would have given some account of the levels of low frequency noise occurring. In assessing the SNR, the authors proposed the use of high and low percentile levels (e.g. L_5 and L_{90}), which they considered, should be a realistic measure of SNR during periods of classroom instruction by the teacher. It is an interesting proposition and would provide a very straightforward approximation of SNR from a single monitoring event of sound pressure levels. Picard and Bradley[35] suggest that conventional methods for determining speech-to-noise ratio can overestimate speech levels by integrating the signal (voice of the teacher) with background noise, which is a characteristic of using exceedance levels. More work on the concept of using exceedance levels to estimate signal to noise ratios is certainly warranted. Wilson et al[8] found that approximately 69% of teaching time occurs as interactive teaching and group work with the teacher moving around the classroom, while only 12% of teaching time occurs in didactic whiteboard teaching from the front of the room. The acoustic dynamics are very different with these two basic styles of instruction. In group work, higher levels of background noise were found as children complete their tasks by interacting with each other and the teacher who moves around the room. This has been described as ‘on the mat’ style of teaching by Wilson et al.[8] However, when the teacher stands close to individual students and speaks to them, the signal would be stronger than from a distance. When giving traditional didactic teaching from the front, one would expect the background sound levels to be lower than what occurs the modern style of teaching[*] as the teacher is commanding the students' attention, but a weaker teacher's voice (signal) as distance increases.

The report describes classrooms as noisy places with 59% of teachers surveyed reporting that while student-generated noise comprised most or all noise created inside

[*]This often involves group work with the teacher moving around the classroom addressing individuals or small groups of children rather than the whole class from the front

the classrooms, a large number of teachers surveyed (86%) indicated difficulty at times with externally generated noise intruding into the classroom. Some of these sources included road traffic, other classrooms, sports fields, lawn mowing, corridors, decks (from foot traffic) etc. The 'other' noise included rain, and electric hand dryers from toilet areas.

The authors described classroom noise as a serious occupational hazard for teachers due to speaking for long periods of time over elevated noise levels and found that a third of teachers they surveyed had to often raise their voices to be heard. Such judgements are subjective because there would be quite a difference between a speaker with a naturally loud, well-projecting speaking voice when compared to a person who naturally speaks softly.

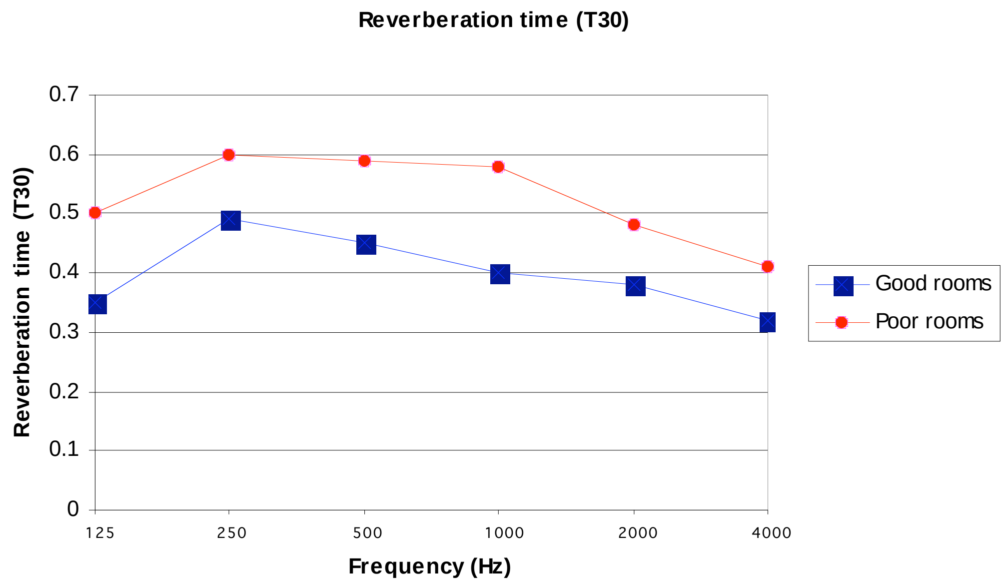
It is interesting to note that the occupational sound level exposure of teachers was not assessed in this study nor was any assessment made of teachers' hearing. Teachers, like any other workers, should be subject to the noise provisions of the New Zealand *Health and Safety in Employment Act 1992* and *Health and Safety in Employment Regulations 1995* although these provisions are probably not legally enforceable as this legislation was never designed to control noise generated in educational settings.

The hearing impaired subjects were found on average to be 1 year behind the mean reading age and two years behind the normal hearing subjects. Allen[11] reported similar findings. An interesting observation was that children with mild to moderate hearing loss who were fitted with conventional hearing aids (without FM radio hearing aids) performed poorly. Those children with severe hearing loss who were fitted with FM radio hearing aids (in addition to their normal hearing aids) performed quite well in both live noise and recorded noise learning environments. This suggests that those with mild hearing loss could be severely disadvantaged, due to the difficulty of filtering out the signal from high levels of background noise received either naturally or through their hearing aids. It is worthy of note that the FM hearing aids fitted to those with severe hearing loss will deliver the signal directly to the student's ears and therefore largely bypasses the levels of background noise encountered by the other students. It appears from this evidence alone that the provision FM hearing aid systems to those students with mild hearing loss is highly desirable in noisy classroom settings.

Other special needs children with developmental delay, speech and language deficits or known to be adversely affected by noise were not assessed in this study. It would also be a particularly interesting study to identify and evaluate the children with a range of disorders that are known to be affected by noise such as Down syndrome, developmental delay, autistic spectrum disorders and attention-deficit/hyperactivity disorder etc.

The researchers selected a small number of classrooms rooms each of those identified as 'good' and 'poor' acoustically from the teachers' responses and measured reverberation times (RT 30) while rooms were occupied. These results are presented graphically below.

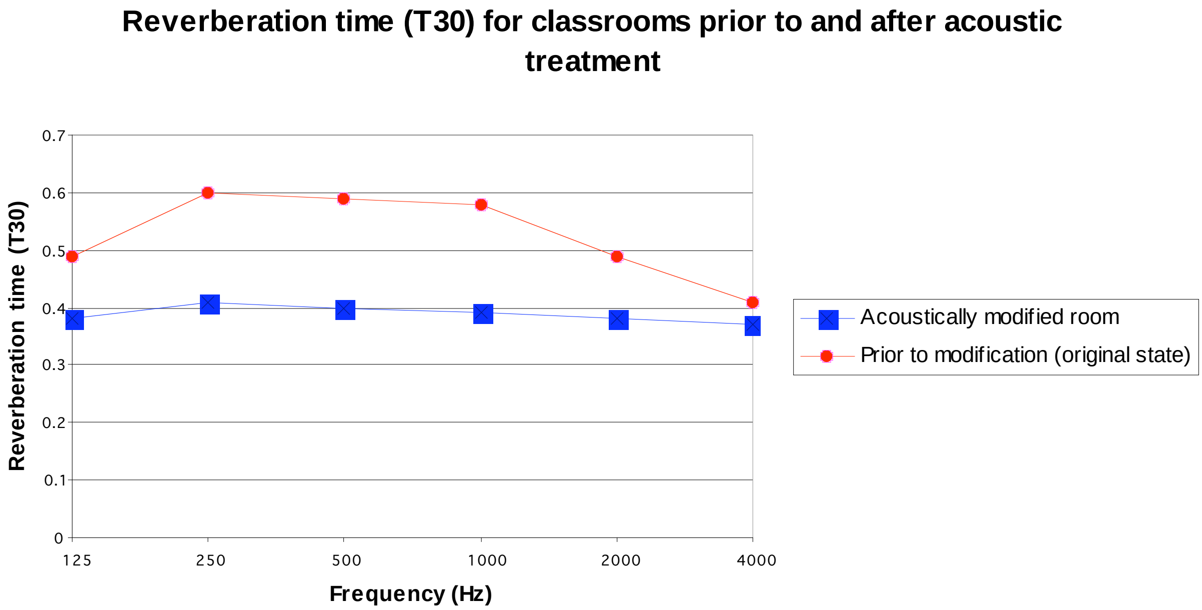
Figure 2-3 Average occupied reverberation time measurements for good and poor classrooms



Source: Wilson et al[8]

The researchers carried out modification to the six rooms with poor acoustic ratings with commercially available acoustic ceiling tiles. This reduced reverberation times to the same level of rooms rated as having good acoustics. Details of products used were given. The results achieved are presented graphically in Figure 2-4 (below).

Figure 2-4 Average reverberation times in occupied classrooms in original state and following acoustic modification



Source: Wilson et al[8]

Follow-up surveys on the modified rooms proved to be very favourable with most rating the modifications considerably better than previously. In addition, it would have been advisable to undertake reverberation times in unoccupied classrooms as the presence of children and their teacher will have an effect. While it may give a more realistic indication of what reverberation occurs during lessons etc, it introduces more variables in directly assessing the effects of acoustic modifications to the rooms.

The authors made a number of key recommendations.[8] These included the building of classrooms to meet an appropriate acoustic standard[34] and modifications for existing classrooms of poor acoustic design. Carpet was recommended to reduce noise from foot movement and furniture scrape. The authors drew attention to the extent of external noise intruding into the classroom and advised making teacher and school administration staff aware of the impacts of this type of noise.

Recommendations, in addition to those proposed by Wilson et al,[8] are presented in Section 2.9 of this chapter (see page 2-34).

2.6 Review of existing studies

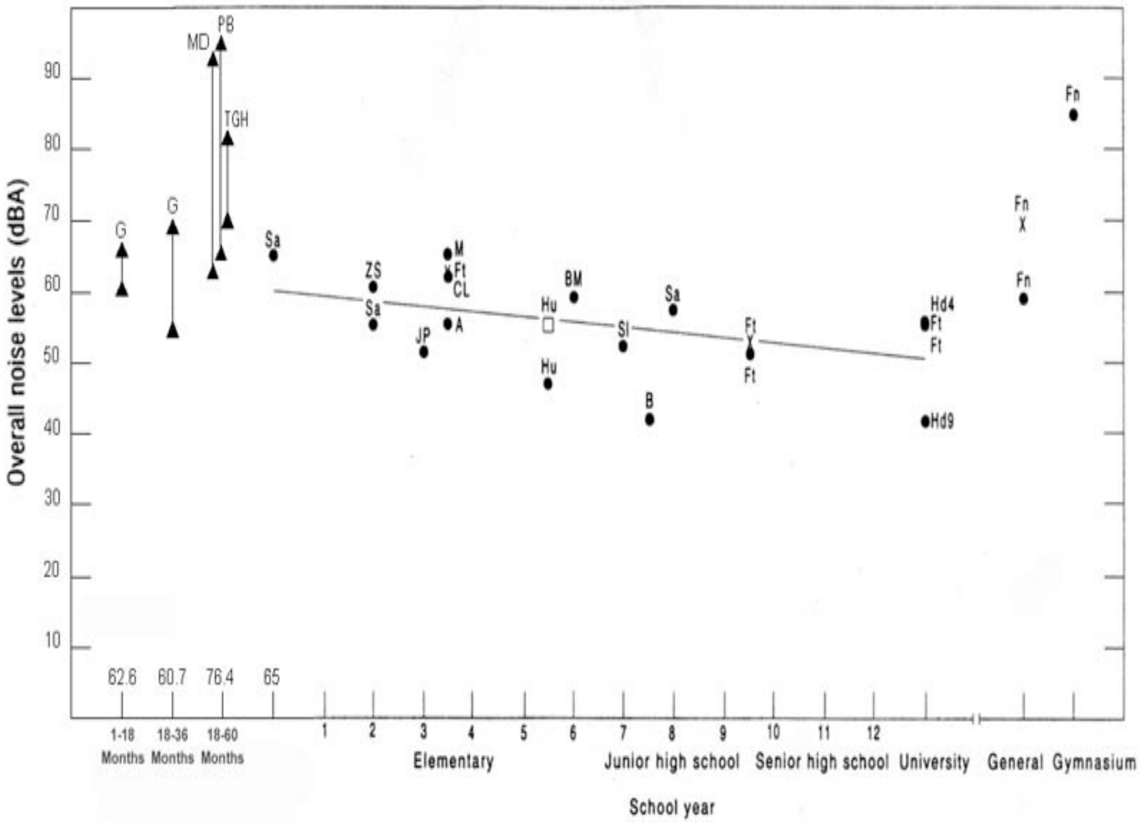
Problems of classroom noise are not limited to New Zealand and there seem to be issues in many countries over noisy classrooms and learning environments. Picard and Bradley have recently published one of the most comprehensive reviews of noise and speech interference in classrooms.[35] These authors find that excessive ambient noise and reverberation in classrooms are serious obstacles to learning principally because of the effects on speech recognition. Significantly they point to these combined effects being extremely detrimental during the early years of school and preschool where student groups are noisier while learning the essential skills upon which all other knowledge is built, i.e. the basics of literacy and numeracy.

These authors[35] cite the 1995 survey of physical conditions of school facilities in the USA by their General Accounting Office where 28% of all schools across the USA were found to be excessively noisy. No such nationwide study has yet been done in New Zealand. The above study by Wilson et al[8] suggests that New Zealand classrooms suffer similar problems. They suggest the open plan style classrooms (or barns as they are sometimes referred to), which were widely promoted in many countries, to be a major cause. These comprised large open teaching spaces where several groups could be taught simultaneously resulting in spill over of teachers' voices as well as noise from student activities. While it was intended to foster shared learning experiences, the lack of acoustical privacy and the combined shared noise quickly became the undesirable outcome. Investigations pointed to the open plan style actively contributing to the level of noise and found that intruding speech from adjacent groups to be the most disturbing. A-frequency weighted time-average background noise levels in the range of 66 - 73 dB were a characteristic of these learning spaces.[35]

Ambient or background noise is generally of greater nuisance potential than excessive reverberation times, because it often in excess of values detrimental to speech recognition. Reverberation is more easily controlled as students themselves contribute significantly to absorption.[35] One can most commonly experience this in large reverberant churches, where the difference in reverberation effects is very noticeable with an empty church when compared to a large congregation fully occupying the building. When the number of students increase, reverberation may decrease to acceptable values whereas the ambient noise by students is expected to increase. Picard and Bradley cite a number of reports where A-frequency weighted noise levels increase from 5 to 33 dB. Despite this, reverberation cannot be regarded as a minor issue. Reverberation times exceeding 0.6 seconds can have deleterious effects on speech recognition. Unlike churches, classrooms usually have much smaller volumes of 200-400 m^3 and accommodate 20-35 students.[35]

As a result of personal communication with Picard[36], the original Figure 1 of his report,[35] has been modified to include figures from studies in early childhood centres including this work.
(The pilot study reported in Chapter 3 is shown as MD in Figure 2-5 below).

Figure 2-5 Summary of overall ambient noise levels typically found in classrooms occupied by normal-hearing children.



where:

- ▲ $L_{Aeq\ 8\ h}$ for early childhood centres
- • L_{Aeq} for traditional classrooms with students waiting for instruction or writing down an examination
- ♣ as for above measurements repeated with windows opened
- x open plan classroom with student s waiting for instruction or doing examinations.

Grades or years at school are shown from 1 (new entrant) to 12 with early education and university measurements shown either side. PB, Sa, TGH etc refers to the specific studies used to compile the figure by the authors.

Reprinted with kind permission of Picard[36]

When considering such data from a variety of sources, the lack of standards or codes of practice in measurement and assessment of noise in early education becomes an important issue. The placement of sound measuring equipment, the lengths of time sampled and the type of equipment and descriptors used become critical in obtaining representative samples and comparable results. To give an example, the microphone of any sound level meter used should be placed at the height of the hearing zone of teacher and pupils. Due to the possibility of tampering and obstruction of movement around the room, this is not often practical or feasible. Researchers will devise their own plans for such assessments, which can vary greatly from one study to another and have a significant effect on results obtained. The use of C-frequency weighted time-average levels by Wilson et al[8] when other researchers have used A-frequency weighted levels is a good example.

Picard and Bradley[35] point to the current scarcity of knowledge regarding noise in classrooms and quote two papers by Moodley[37] and Sanders[38] which addressed the noise issue at the most critical stages, i.e. the early education and new entrant levels. They described the measuring techniques at the time this research was conducted as being severely limited when compared to the modern techniques, making valid comparisons unreliable. These authors concluded that there was an urgent need for comprehensive data on noise issues in early education and elementary (primary) school classrooms, which would include establishing some standardized procedures to measure signal (speech)-to-noise ratio in conditions representative of speech communication in classrooms.[35]

Some studies cited by Picard and Bradley[35] where separate contributions of students and ventilation systems were identified may not be widely applicable in New Zealand. Due to the New Zealand temperate climate, few early childhood centres and classrooms have mechanical ventilation systems. While New Zealand facilities may largely be exempt from the issues of noise in ventilation systems, natural forms of ventilation have their own set of consequences, especially when windows are opened (noise intrusion from outside activities) as found by Wilson et al.[8]

Picard and Bradley[35] find that noise levels in classrooms are usually of more serious concern than reverberation due to small spaces of early childhood facilities.
They indicate the need for more in-depth research to overcome interfering noise levels in classrooms and similar learning spaces. They suggest the following:

- The rationale for excessive background noise to impede recognition and verbal learning in classrooms must be fully described and the associated risk specified.
- The reporting of children's speech recognition performance in unfavourable listening conditions, as may be representative of classes in session. An important point raised by them was that besides providing the basis for establishing performance criteria and leading to acoustical standards for classrooms, it will help identify the more sensitive subgroups and specify the need for remedial solutions.

The current literature on noise in classrooms and learning spaces focuses heavily on the effects on mainstream children with normal healthy hearing and those with hearing impairment. Children with other forms of auditory and / or developmental disabilities are barely considered. Yet, comprehensive reports by Shields[39] and Janzen[40] on autism and related disorders, as one example, point very strongly to the likelihood of these children being profoundly affected by the type of noise found in classrooms. It can therefore be reasonably generalised that children with these disabilities could be severely affected.

A 1980 study by Zentall and Shaw[41] specifically examined the effects of student-generated noise on hyperactive children when compared to a control group. Due to the age of the study and the more recent advances in the diagnostic characterisation of such disorders, it is possible that children in this study may now fit the current diagnostic criteria of attention-deficit/hyperactivity disorder (ADHD).[42] The authors used a teachers' rating scale developed by Conner[43] in 1973 to assess hyperactivity. Two groups of students (hyperactive group and a control group) were subjected to typical noise generated by student activity. The authors found significantly lower performance on mathematical and alphabet reading tasks with a higher level of activity with the hyperactive group. In other words, both groups of children were affected but the hyperactive group was the most profoundly affected. It would be interesting to repeat this study with the modern diagnostic tools available such as the current diagnostic criteria for such disorders.[42] A study by Evans et al[44] showed that children in noisy environments are less likely to solve difficult challenging puzzles and are more likely to give up on a task. They describe the associated feeling of frustration and anger as being part of the overall picture in chronic exposure to noise.

Picard and Bradley[35] reported extensively on background or ambient noise affecting speech production, recognition and learning in classrooms. They report that background noise competing with the voice of the teacher to produce a less than ideal signal (speech)-to-noise ratio of 0-10 dB will inevitably result in difficulties in communication for both speakers and listeners. They quoted studies where 70% teachers reported problems with voice strain at some time with 17% indicating it to be a current issue. Compare this to the New Zealand study by Wilson et al[8] where 80% of teachers reported vocal fatigue as an issue. Voice problems have been described in both studies as a serious occupational hazard and a highly prevalent recurrent and incapacitating condition.[8,35] They also raise the issue of progressive vocal exhaustion from continual use of the voice, and concluded that decreasing intelligibility as a result of altered voice quality and level would represent a serious impediment to academic progress.

There are a number of accounts of reading deficits and problems associated with children living near sources of transport noise. A study by Evans and Lepore[45]on the non-auditory effects of noise in children reported reading deficits in children living near major sources of transport noise. Another study by Evans and Maxwell[46] found that Year 1 and 2 school children with normal hearing, that were exposed to chronic aircraft noise, had significant deficits in speech perception and reading skills when compared to children in a quiet school.

Picard and Bradley[35] corroborate the findings of our New Zealand work in assessing noise in early education and report that preschool children and new entrants would be among the noisiest groups of children. They report A-frequency weighted time-average levels averaged over 8 hours ($L_{\text{Aeq 8 hours}}$) as being between 72-80 dB, which is in the same range as found in this work. Picard and Boudreau[47] found representative noise levels between 66-94 dB for 10 minutes. This was of the same order as the pilot study (reported in Chapter 3), where the quietest activities, such as sleeping, ranged from A-frequency weighted time-averaged levels (L_{Aeq}) of 63-69 dB. Events such as a children screaming, or very noisy activities reached levels of 94 dB for similar periods. In the pilot study, a short burst of noise (integrated over 1-2 second duration) reached over 100 dB A. Such levels of noise exposure can induce cochlear damage in preschool and new entrant children, but would have no such effect in adults. Such evidence is indeed disturbing that noise exposure could be hazardous with the potential damage such as noise-induced hearing loss.[35] Picard and Bradley suggest that increased noise levels in the years of early education and new entrant classes are due to these children becoming engaged in regular structured activities. These children have limited attention span and are learning classroom discipline. It is expected that due to the casual semi-formal structure of the early years of education, young children would be more talkative and exuberant, resulting in a complex mixture of sounds including talking, furniture movement and shuffling of books and stationery.[35]

In their summary, Picard and Bradley[35] find that excessive noise exposure of young children will induce a synergistic interaction of noise and developmental factors. They suggest that this would be particularly detrimental to speech understanding right at the beginning of their schooling (in early education and new entrant years) in addition to other adverse consequences.

There are a number of studies which show a clear trend for spoken word recognition to increase with age for normal hearing school children and for this skill to fully develop by age 18.[35] This evidence is corroborated by Nelson and Soli.[7] Picard and Bradley[35] conclude that despite confounding factors such as the variations of degree of hearing loss or the use of hearing aids and other standard prosthetic devices in classrooms, the performance of the hearing impaired is well under the performance levels of their normal hearing peers.

Hearing aids are known to provide little help in each situations amplifying both speech and other competing signals and therefore failing to increase signal (speech)-to-noise ratios. A main thrush of new technologies is to improve the signal (speech) against other competing noise.[35]

2.7 Levels of hearing loss among New Zealand children

Vision and hearing screening of preschool, new entrant, and primary school children has been carried our for many years in New Zealand by public health authorities. The programme is contracted by the Ministry of Health and coordinated by the National Audiology Centre. Vision and hearing technicians, who are employed by district health boards to test children in their geographical areas, do the screening.

The Hearing Report of 1984[48] by the Board of Health indicated failure rates in 1983 as shown in Table 2-1 but pointed out that these results may be unreliable as they were based on individual tester returns, and was not part of a uniformly conducted study. Separate estimates for Maori and Pacific Island children were not available. Screening of preschoolers in 1983 would have been carried out with pure tone audiometry, which was subsequently changed to tympanometry due to the difficulty of conducting pure tone audiometry with preschool children. Furthermore, testing was often done in noisy test conditions adding to the unreliability of these evaluations. In regions such as Northland and Gisborne with a large number of Maori, high failure rates of over 20% were reported in the 1984 study.[48] The change of the testing regime from pure tone audiometry to tympanometry also completely changed the criteria being assessed from the threshold hearing level to middle ear compliance. Ignoring the very different demographics of the population of 1983, the difference in testing protocols and outcomes compared to that of 1995 and 2000, and the question over reliability of the 1983 results, there seems an obvious reduction in numbers of children failing to meet the hearing screening criteria. It is difficult to ascertain how much, if any, of the fall in failure rates /referrals is due in part to overall improvement in the hearing ability of young children or the move to a more reliable testing regime.

Table 2-1 The New Zealand hearing screening statistics for 1983,[48] 1993-4 [49] and' 2000-2004 [50,51,52] are given below:

Reporting period	Preschool (3 years old) Tympanometry Failure (%)				New entrant (to primary school) Failure (%)			
	Overall	Maori	Pacific Is	Other	Overall	Maori	Pacific Is	Other
1983	15.5	*	*	*	19.2	*	*	*
1993-4	*	16.4	12.5	7.5	*	13.9	14.7	7.2
1999-0	5.7	11.6	9.3	4.3	*	13.1	16.4	5.1
2000-1	6.3	13.1	11.4	4.7	6.4	11.3	10.9	4.5

* denotes figures that cannot be obtained.

From 2002, reporting was changed to include Asian children and Pakeha (Caucasian) children under separate categories. Reporting was changed in 2003 from “failure rates” to “referrals.”

2.7.1 New Zealand hearing screening protocols[53]

Tympanometry is carried out on old preschool children (aged 3-4) for the screening of middle ear infections and problems. Pure tone audiometric screening is used for new entrants to school (aged 5-6). While it would be desirable to screen hearing levels in preschool children, the difficulty of doing these outside an audiology clinic preclude this option. Tests can also be requested by parents, teachers or a medical practitioner, dependent on genuine concern.

The New Zealand Ministry of Health use the following hearing screening criteria for testing preschool and school children. These criteria constitute pass/fail rates and referrals:

1. **Pure tone audiometry* for new entrants**
    - Pass criteria - no further action required
        - 20 (or less) dB at 1000, 2000, 4000,Hz
        - 30 dB (or less) at 500Hz
    - **Marginal failure requiring a retest**
        - Results elevated but do not meet or exceed hearing loss of 45 dB on two frequencies
        - Fail criteria – immediate referral
        - Hearing loss of 45 dB or greater on two or more frequencies.

2. **Tympanometry#**
    - **Pass criteria**
        - Tympanogram shows a peak (rising and descending graph) i.e. a Type ‘A’ tympanogram
    - **Marginal failure requiring a retest**
        - Tympanogram is flat (B/C tympanograms) (i.e. no peak or physical volume (PV) between 0.3-1.5 ml
    - **Fail criteria – immediate referral**
        - Tympanogram is Type ‘B’ flat (no peak and physical volume (PV) less than 0.3 ml

In both cases a retest (also referred to a serial test) which does not meet the pass criteria, then becomes a fail and referral. It is not necessary to carry out audiometry on children already under the care of an audiologist or wearing a hearing aid. Although not listed in the protocol, the testing of some special needs children such as those on the autistic spectrum would, in many cases, be impossible and distressing for the child. Tests would then have to be carried out by an audiologist.

* Typical audiograms are given in 6.3 Hearing impairment and deafness (Chapter 6).

The procedure and examples of typical tympanograms are given in 6.2.2.1 Tympanometry (Chapter 6)

Table 2-2 National hearing screening failures and referrals for preschool and new entrant children (2001-2004).[50, 51, 52]

Reporting Period	Preschool (3years old) tympanometry - Failure %(Referrals*)					
	Overall	Maori	Pac Is	Asian	Pakeha Euro	Other
2001-2	7.8	11.8	14.9	7.2	7.1	5.3
2002-3	6.9	11.1	14.3	5.7	3.4	4.4
2003-4*	7.1	10.5	11.3	5.9	4.8	5.7

Reporting Period	New entrant (primary school) – Failure % (Referrals*)					
	Overall	Maori	Pac Is	Asian	Pakeha Euro	Other
2001-2	7.8	12.1	17.1	5.0	4.3	6.1
2002-3	8.1	12.6	16.1	5.6	3.9	7.2
2003-4*	6.5	9.9	13.1	4.5	3.7	4.6

(NB from the 2003-2004 period the terminology changed from “failure” to “referral” as shown by *)

The most recent screening statistics of 2003-4 period appeared to show some improvement from the 1993-4 results but is still below the public health goals set by the New Zealand government in 1997 to reduce hearing loss in new entrant children to 5% or less by the year 2000. The high levels of failure rates in Maori and Pacific Island children are still cause for serious concern.

The effects on the educational achievement of those individual children with hearing impairment in a mainstream-learning environment, who are struggling to understand their lessons and instructions from their teachers, is of major concern. While the consequences of hearing loss in educational achievement and outcomes has not been widely reported, de Silva,[54] the author of a large New Zealand multidisciplinary study which has monitored a number of children right from birth into adulthood stated that significant hearing loss puts these children as much as 1-2 years behind their peers in high school, which is a significant educational delay. This puts these children at high risk of failure and dropping out of the education system with the inevitable consequences of lack of qualifications and skills. De Silva stated that there is anecdotal evidence that this group are at higher risk of facing problems later in life with criminal records.

The Hearing report (1984)[48] documented hearing loss among prison inmates. In a study of 100 Caucasian and 100 Maori prisoners with hearing impairment, ear disease and adverse social history, audiometric results were analysed using:

- Average dB loss over 500, 1000 and 2000Hz.
- An NAL (now National Acoustics Centre) scale in existence at the time, where a normal ear did not score and a disability of 5% or above was regarded as eligible for compensation.

The average dB loss by ethnic character for the better and worse hearing ear is shown in Table 2-2.

Table 2-3 Historical record of hearing loss among prison inmates.

	Maori		Caucasian	
Average dB loss	% better ear	% worse ear	% better ear	% worse ear
< 15 dB	40	17	63	46
15dB – 29 dB	57	72	37	51
30dB +	3	11	-	3

Source: Board of Health[48]

The table shows that 60% of Maori and 37% of Caucasian inmates had a hearing loss of 15 dB or greater in their better ear (48.5% combined) while 83% of Maori and 54% of Caucasian inmates had a hearing loss of 15 dB or more in their poorer ear (68.5% combined). The study concluded that prison inmates had hearing impairment of seven times greater than would be expected in the general population at that time.

Up to date studies on hearing loss among prison inmates are long overdue, but from the levels of persistent middle ear infections still prevalent among children, it is reasonable to assume that hearing loss among prison inmates is still of serious concern and requires urgent investigation. It is well known that Maori are greatly over represented in New Zealand prison populations and the obvious anecdotal correlation with their elevated levels of hearing impairment cannot be ignored. An investigation is now urgently needed to establish if a link exists between the levels of hearing impairment in Maori, their levels of educational achievement and representation in prison populations and crime statistics.

2.8 Summary

Studies in New Zealand and overseas show classroom noise in schools and preschools to be of serious concern for both teachers and pupils. It appears that the noise levels are generally the greatest in the early education and new entrant years. Voice strain of teachers and hearing loss have been identified as serious concerns for both pupils and their teachers. Excessive noise levels, while impacting on all children, were found to have the greatest impact on children with hearing impairment and other auditory disorders. Anecdotal evidence appears to link hearing impairment with increased failure rates at school and the inevitable consequences which in some cases leading to criminal activity and imprisonment. The failure / referral rates of the New Zealand hearing screening statistics were reported for the 1993-4 year and all the data available since the year 2000. The Ministry of Health target to reduce the failure rate of new entrant (school) children to less than 5% by the year 2000 has not been met with reported failure rates in the 2003-4 screening period still exceeding the 5% figure. Recent data on hearing loss among prison inmates is not available but a 1984 report found high levels of hearing loss among prison inmates to be 7 times higher than the general population with a rating scale in use at the time.

There is now an urgent need to establish standardised procedures for the measurement and assessment of noise levels in education and for the accurate assessment of signal-to-noise ratios. The establishment of international procedures would enable researchers in many countries to compare data with greater certainty than what is currently possible.

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3 *Noise in New Zealand early childhood education centres - A pilot study*.

3.1 Introduction

Clearly exploratory studies are needed to assess the various types of early childhood education facilities in New Zealand, the various conditions which give rise to noise levels, and the typical noise exposure levels to which children and their teachers are subjected.

With these conditions in mind, a 3-month pilot survey was carried out in a range of children facilities and environmental conditions to investigate typical noise exposure levels experienced by children and their teachers. Written permission was obtained from the governing bodies and individual centres participating in the study. Parents and teachers, were all notified in writing in accordance with the requirements of the governing bodies and individual head teachers. Parents of the children were notified in writing as to the nature of the research, the rights of the children present, and obligations of those conducting the research.

Early childhood centres are divided into the following categories (Table 3-1), which are defined by the current legislation[1].

Table 3-1 Classification of early childhood centres

1. *All day* centres	2. *Sessional* centres
a. All children under 2 years old	a. All children under 2 years old
b. All children over 2 years old	b. All children over 2 years old
c. Children of mixed ages	

Eight *all day* centres and five *sessional* centres, as licensed by the Ministry of Education, were selected for evaluation. The *all day* centres included centres in each licensing category as shown above in Table 3-1. The five *sessional* centres were selected from kindergartens in the greater Wellington area.

3.2 Experimental

No standards exist for specifically measuring noise in early childhood centres and the effects on children. While the most effective way of monitoring a child's exposure is to fit a logging personal sound exposure meter (PSEM) to individual children, ethical considerations and practicalities precluded this option. The equipment was bulky and heavy, and could not be supported on the clothing of the child. The likely exposure a child would receive was simulated by an adult using a Cirrus 831A integrating sound level meter as a PSEM with the microphone placed at the height representing the ear level of the child, selecting a child at random and moving around the centre with that child. In addition, different activities were monitored to gain information on the noise levels generated from very quiet activities such as sleep/rest to those generating high levels of noise. One-second time histories were recorded. A detailed log was kept to relate the data collected to actual sounds and activities.

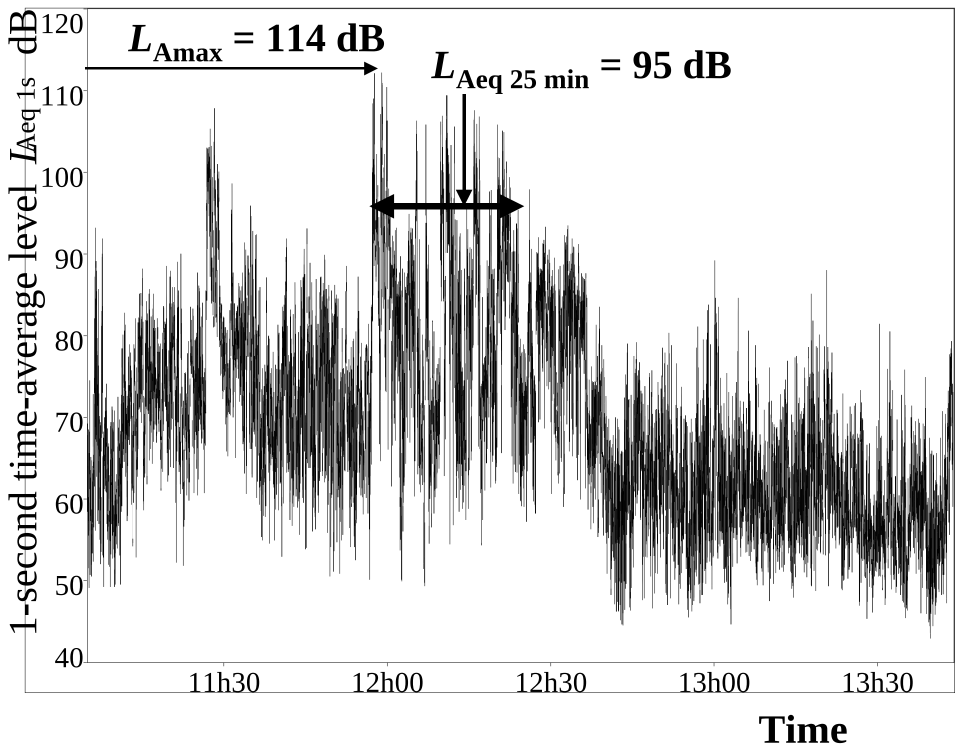
The daily sound exposures (DSEs) of ten staff members at *all day* centres and three *sessional* centres were also measured. The noise exposure of teaching staff was measured by fitting PSEMs to workers, which they carried with them to monitor their exposure to noise over their full working day. The daily sound exposures were measured using Class 2 Quest PSEMs in accordance with the approved code of practice.[2] The New Zealand legislation[3] requires an employer to take *all practicable steps* to ensure that no worker be exposed to a time-average level (L_{Aeq}) greater than 85 dB for a maximum of 8 hours a day, 5 days a week, or the equivalent sound exposure. That is a maximum daily sound exposure of 100% dose, or alternatively in acoustical terms, 1.0 pascal-squared hour (Pa^2h).

3.3 Results and Discussion

3.3.1 Children's exposure to noise

A-frequency weighted time-average levels (L_{Aeq}) over long periods ranged from 74 dB to 79 dB. (See Figure 3-1). The highest of these time-average levels were for specific events such as distressed children screaming, which in one case reached 95 dB over a 25 min period ($L_{\text{Aeq 25 min}}$.= 25 dB). The maximum sound pressure (L_{Amax}) reached 114 dB. (see Figure 3-1 below). Other events, which raised excitement and noise levels from the children, were rough and tumble play and active games such as table soccer, which recorded A-frequency weighted sound levels as high as 87 dB. Noise levels often dropped significantly (to around 70 dB) during 'mat times' when children were encouraged to sit quietly and listen to their teacher. The quietest times were when all or most of the children were sleeping or resting. Levels during this period dropped to 63-69 dB. Considering that the recommended background sound level in an unoccupied classroom is 35-40 dB, such high levels are not acceptable.

Figure 3-1 Time history of noise levels in an early childhood centre.



It was interesting to note that noise levels outside in the playground can be as high as those recorded indoors. An A-frequency weighted time-average level for 20 minutes in one playground, which is shared by a primary school, reached 82 dB. Besides the noise the children were making, there were metal gates clanking, as they were opened and shut. A-frequency weighted sound pressure levels taken within a meter of the slide in Figure 3-2 (with metal trays) reached 87 dB when children were playing on it. It appeared that no sound attenuating material had been fitted during construction to stop the tray resonating and therefore reduce the sound. Staff indicated that poor weather which confines children indoors, results in frustration for the children and a perceived increase in noise levels. There did seem to be an increase in levels but this preliminary study did not collect enough comparative data to verify this.

Figure 3-2 The noisy slide

Observations revealed a considerable amount of unnecessary noise such as door banging, noisy furniture, play equipment, toys and appliances being used. Simple actions such as replacing worn rubber caps on furniture legs can have a marked reduction in noise when furniture is moved. Playground equipment should be constructed and maintained to reduce noise when in use. Simple rubber mounts on gates and doors could reduce noise from opening and closing. Some staff tended to raise their voices to be heard over the noise levels in the facility which all contributes to increased noise levels. Regional Public Health (the public health authority of the Wellington region), in its monthly newsletter, strongly advocates the introduction of quiet and rest times in their advice to childcare centres under their jurisdiction.[4] The authority also strongly advocates the need for designated quiet spaces to give children time out from their busy centre lives. Large well-ventilated sleeping spaces are therefore of paramount importance as is the establishment of quiet spaces where children can retreat.

This work showed that where sleep times were successfully implemented, the 1-second time-average noise levels ($L_{\mathrm{Aeq\ 1s}}$) over these periods of time dropped sharply. Sleep rooms can be noisy when children are distressed. In addition, those sleep areas without separate air spaces, are subject to noise intrusion from other activities in the centre.

3.3.2 Staff Exposure to Noise

3.3.2.1 All day centres

It wasn't possible to measure the full daily exposures for all the staff. Staff were rostered different hours from day to day. However of the 10 staff evaluated from the *all day* centres, 3 staff received excessive daily sound exposures of 111, 121 and 144% dose. Two others came close to this level and could have exceeded the maximum dose if they had been monitored with similar levels of noise for a full 8-hour day. While the remaining staff monitored had levels well below the maximum daily sound exposures of 100%, these workers were monitored for a 6 to 7-hour day due to their rosters.

3.3.2.2 Sessional centres

Daily sound exposure rates are of less concern for the *sessional* centres as staff have considerably less contact time with children than those in *all day* centres. In *sessional* centres (kindergartens), the maximum number of contact hours is usually 6 hours per day 3 days a week with morning and afternoon sessions and on the remaining 2 days, there is only one 3½ hour morning session. All staff were monitored for 3 to 3½ hours during morning sessions. It is worth noting that two staff, who were monitored, were exposed to an A-frequency weighted time-average level (L_{Aeq}) of 85 dB and noise exposures of 47 and 39% dose. The third staff member was exposed to noise with an A-frequency weighted time-average level (L_{Aeq}) of 82 dB and a daily sound exposure of 20%.

The lowest personal noise exposure recorded in all of the centres was 9% dose with an A-frequency-weighted time-average level (L_{Aeq}) of 75 dB. This *all-day* centre had a smaller number of children attending than usual (15 out of 30 enrolled children) due to the school holidays. Even though the staff member worked for 7 hours, she had a variety of duties, which included both contact, and non-contact duties. This would appear an effective strategy to reduce individual exposure to noise.

3.4 Conclusion

Few childcare facilities have comprehensive policies to protect staff and children from the effects of excessive noise. Staff in childcare facilities are generally not monitored for excessive noise exposure as happens for other workers in noisy workplaces. Solutions to noise in early education are not straight forward, as staff cannot interact effectively with children if they are wearing hearing protectors. In addition, little attention is given to the attenuation of noise in the construction of childcare buildings and playgrounds. An unexpected finding of this study was that noise levels outside could also be as high as those recorded indoors.

This work suggests that exposure to noise of the children and staff can be very different in the same environment. Levels measured simulating the likely exposure a typical child will receive, were on the whole, considerably lower than the dose received by staff in the same facility. It would be preferable to directly measure personal exposure of children if suitable equipment which could be fitted to the clothing of young children was available. Teaching staff spend much of their time comforting distressed children who make considerable noise close to the ear of the teacher. Noise levels were shown to rise sharply when distressed children come close to the microphone and this seems a major cause of the high levels of noise exposure received by teachers.

This pilot study revealed the need for a more comprehensive study as some of the few staff evaluated received noise dose levels in excess of that permitted by the New Zealand health and safety in employment legislation.[3] In particular there is a need to individually monitor personal sound exposures of children as well as their teachers but present equipment would be too heavy and bulky to fit to the clothing of young children. New small and lightweight noise doseBadges have just become available which may be suitable. The acquisition and use of these devices will be investigated. General observations while carrying out the study revealed the need to examine building aspects likely to influence acoustical quality. These need to be recorded and the acoustical quality of teaching spaces needs to be assessed. The presence of a wide variety of special needs children receiving educational support and individualized special education in early childhood centres was an important observation and information is needed as to how these children are affected by noise and how this impacts on their educational outcomes.

3.5 References

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4 Speech intelligibility, processing and speech interference levels

4.1 Introduction

The most important method of communication between humans is still speech, despite the recent advances in communication technologies. The human auditory system has the capacity to discriminate differences in the signal received and the ability to assimilate and process information.[1] A serious consequence of noise is that it prevents one person from understanding another whether it is face to face, by telephone or a voice amplification system.[2] Communication, where the listener can clearly see the speaker, is often enhanced by cues such as facial expression, lip reading, and other forms of body language. The importance of such indirect forms of communication is demonstrated by difficulties encountered by those with disabilities such as autism, where there are major deficits in indirect communication skills and abilities.

4.2 Speech and intelligibility

Intelligibility is defined by Webster [2] as the understanding of the spoken word. It does not include the more complex forms of communication such as nuance, the identification of a speaker from his/her voice, or emotions from the tone of voice. Speech is a result of a learned motor behaviour.[1] A speaker generates complex sound waves, which change continuously. These sounds vary greatly in overall sound pressure and frequency content over time. [2] Cues are found between frequencies 100 - 8,000Hz with most acoustical energy of speech falling within the 100 - 6,000Hz range. Of this, the most important cue-bearing energy falls between frequencies of 300-3,000Hz. An informative spoken language must consist of mutually exclusive sounds of which the fundamental elements are called phonemes. These can be described as a unique code related to the articulatory characteristics of a given language.[1,3] Speech also includes temporal features such as loudness, pitch and rhythm, which give a temporal pattern in which the phonemes are embedded.[2] Alongside phoneme discrimination, the study of speech rhythms (called prosody) is required for correct speech perception.[1]

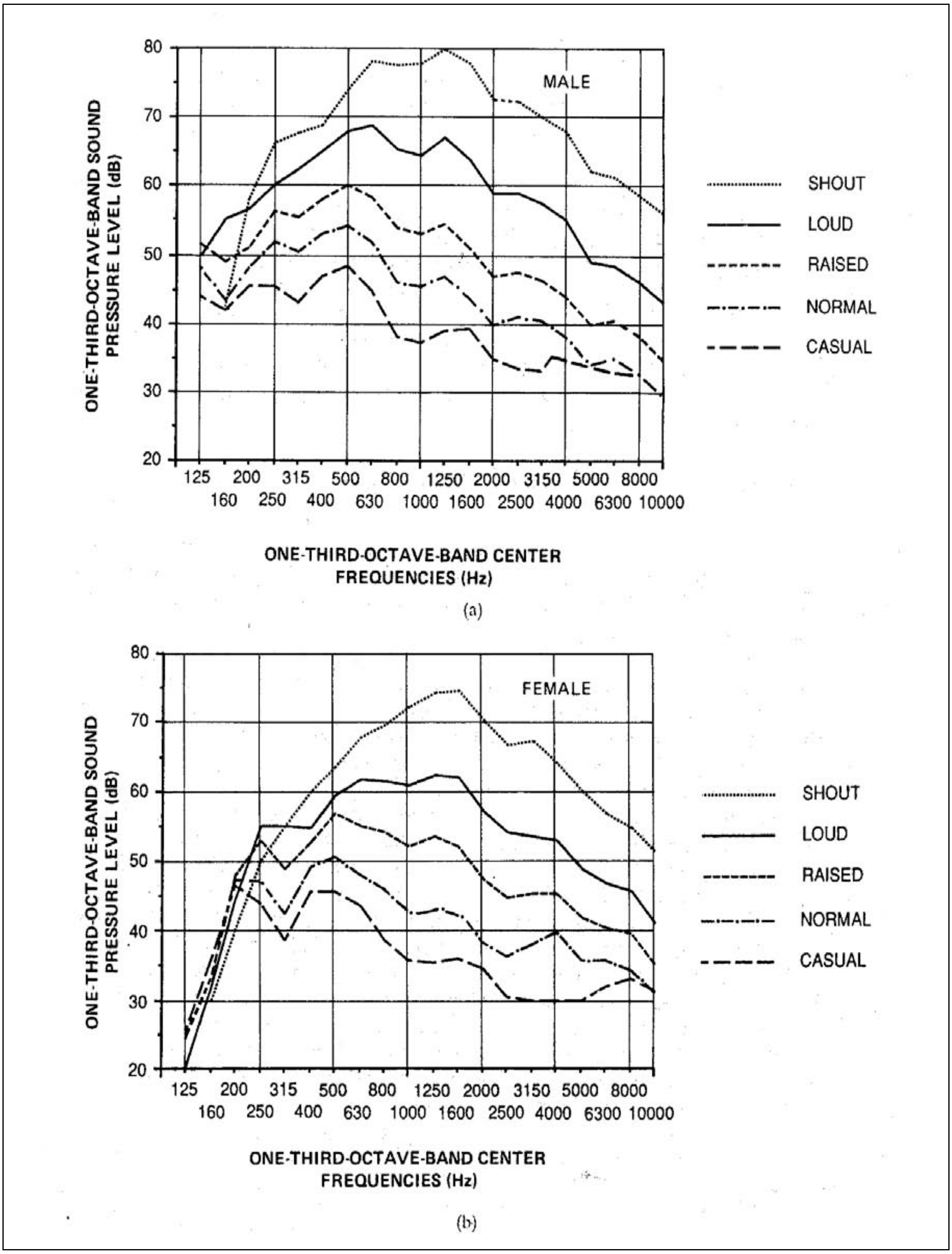
The extent to which the speech signal exceeds the background noise level is known as the signal-to-noise ratio (SNR), which is a function of speech intelligibility.[4] A speaker in a noisy environment must do one of the following if speech communication is deficient:[4]

- Move closer to the listener
- Increase the level of their voice
- Reduce the level of background noise

There is an acceptable limit beyond which the increased levels of speech add to the overall noise level. Communication with a normal voice is easy when only a few people are present. As the numbers rise, the background noise increases until speech communication is near impossible even with raised voices at close range. Hegyold and May[4] describe this as the cocktail party effect.

While the frequency of occurrence of speech varies greatly from one individual and situation to another, Levitt and Webster[5] has given (in Figure 4-1), a long-term average of data of a typical male subject, showing the one-third octave band sound pressure levels versus frequency for typical speaking conditions. This figure shows that the typical male voice is louder (exerts higher sound pressure levels) than the typical female voice in the lower audible frequency range (125-250 Hz). The average male voice when shouting can reach a sound pressure level of 80 dB at 1250 Hz whereas the average for the female voice when shouting will only reach 75 dB at 1600 Hz. The long-term average speech spectra for the male voice is generally higher than that for the female voice for the 5 different vocal effects given across the audible one-third octave band frequencies.

Figure 4-1 Long term average speech spectra in ⅓ octave bands at 5 vocal levels for adult male speakers (a) and adult female speakers (b).



Source: Levitt and Webster[5] and Pearsons et al[6]

Levitt and Webster[5] have also given A-frequency weighted average sound levels of speech for the typical male and female voices for the different vocal effects (see Table 4-1).

Table 4-1 Average A-weighted sound pressure levels for different vocal conditions in quiet conditions.

Vocal effect	Male (dB)	Female (dB)
Casual	53	50
Normal	58	55
Raised	65	62
Loud	75	71
Shout	88	82

Source: Levitt and Webster[5]

What is considered a normal speaking level in one set of conditions may be quite different in other conditions. Such factors include individual differences, reverberation time and levels of background noise. However, the literature suggests that at a 1-metre distance from the speaker, A-frequency weighted sound pressure levels are usually between 50-65 dB[2]. The average level with a speaker in a quiet area is 57 dB at 1 metre. The range of sound pressure levels varies from a whisper at approximately 40 dB to maximum vocal effect at approximately 88 dB with the usual range from 50-75 dB.[2]

4.2.1 Effects of speech level on communication

Speech shouted or spoken loudly is less intelligible than normally spoken speech with the same signal-to-noise ratio.[7] This is because when the voice is raised there is a change in phoneme structure.[9] The vowel sounds are accentuated to a much higher level than consonants especially the soft consonants such as *s*, *f*, or *th*. The vowels dominate and overmask the consonants with are important in speech intelligibility.[8] The speech to noise ratio must be 5-10 dB less than that for speech spoken at a normal level to achieve equal speech intelligibility.[9,7]

When a person speaks in noisy surroundings, they will automatically raise their voice to a higher level. This is known as the 'Lombard effect.'[10] Lazarus has reviewed several studies that show that a speaker will generally increase their voice by 0.4 –0.7 dB for every 1 dB increase of noise level at the ear.[7] This can result in voice distortions and vocal cord stress,[1] all of which will degrade speech production, clarity and therefore compromise speech perception.

Lazarus[7] found the intelligibility of speech that is shouted above a level of 75 dB to be substantially reduced. Assuming that intelligibility up to a level of 75 dB to be constant, for every 10 dB increase past this point, intelligibility is reduced by 15-40% which corresponds to a SNR of 4 dB. This has major implications in the classroom where teachers naturally raise their voices to be heard over the level of noise.[7] The greatest impact is likely to affect those children with disabilities involving speech, hearing, auditory processing and development.

4.2.2 Effects on the listener

A number of studies cited by Lazarus[7] indicate that if the speech level at the ear of the listener exceeds 80 dB A (L_{SA} > 80dB)[*] with a equal signal-to-noise ratio, intelligibility decreases slightly, which has been attributed to overloading of the hearing mechanism. Lazarus estimates that effective SNR is reduced by 1 dB for every 10 dB increase in speech level (L_{SA}) above 80 dB.

4.2.3 Effects of background noise on speech communication.

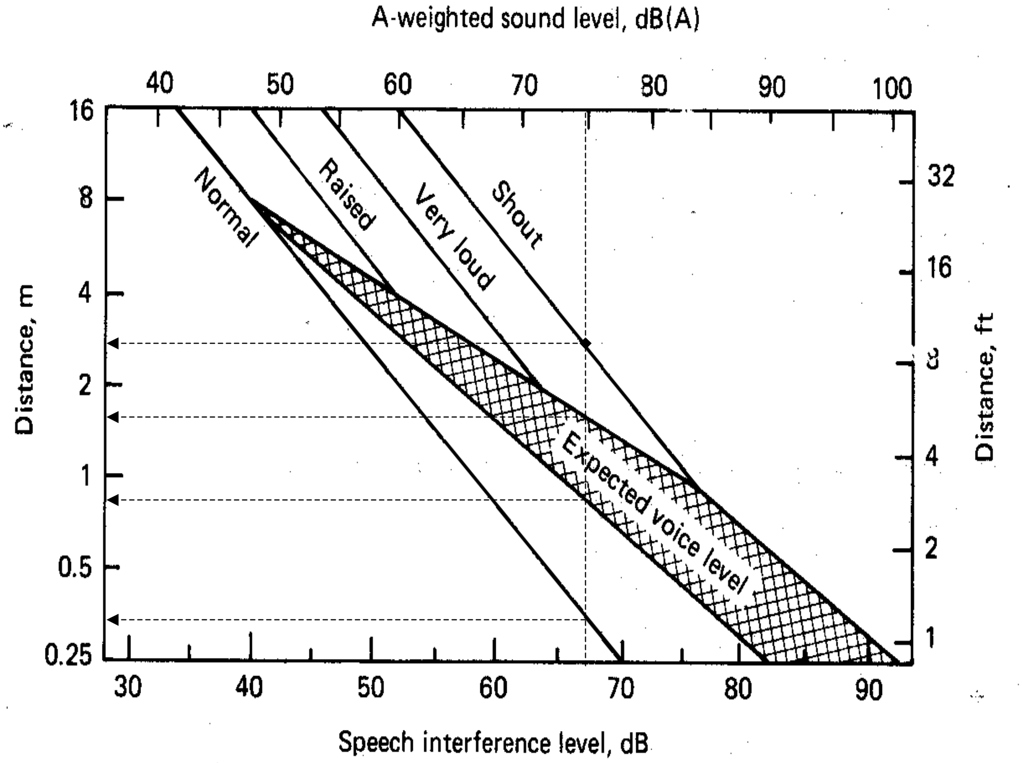
Webster[2] indicates that it is possible to have satisfactory communication conditions (i.e. 95% or more of sentences to be correctly understood) using a normal voice level up to 5 metres with an A-frequency weighted background noise level of 50 dB. As the background noise level rises, the speaker will normally raise their voice 3-6 dB for every 10 dB increase in background noise level above 50 dB.

Levitt and Webster[5] have described how the A-weighted sound pressure level can be used as a measure of speech interference where these sound pressure levels can be used to predict maximum permissible speaker to distances for ‘just reliable speech communication’ in noise. ‘Just reliable speech communication’ is defined as where trained listeners obtain a test score of 70% on phonetically balanced monosyllabic word

[*] L_{SA} is the A-weighted sound level of speech measured across speaking time at a 1 metre distance from the speaker’s mouth and expressed as a time-average level ($L_{sAeq,1 m}$).

lists.[5,11] In this method, the A-weighted sound pressure level of background noise is measured using 'S-time weighting.' As demonstrated in Figure 4-2 (below), a vertical line is drawn from the A-weighted sound pressure level (upper abcissa/axis) and where it intersects the curves indicates the maximum distance between the speaker and listener for 'Just reliable speech communication.'

Figure 4-2 Distances to achieve 'Just reliable speech communication'



Source: Levitt and Webster[5]

The hatched area in Figure 4-1 shows a range of speaker to listener distances in background A-frequency weighted sound pressure levels over 50 dB where the speaker will normally increase their voice by 3-6 dB with every incremental 10 dB increase in background noise level above 50 dB. The lower boundary of this area represents a 3 dB increase while the upper boundary the 6 dB increase in speech level. As an example, a background sound level of 75 dB is shown in Figure 4-1. The distance needed to achieve 'just reliable speech communication' is about 1.6 metres if the speaker raises their voice by 6 dB compared with approximately 0.8 metres if they raised their voice only 3 dB. If shouting, 'just reliable speech communication' will occur at approximately 3 metres and approximately 0.3 metres for a normal voice (not raised with increased background noise). Levitt and Webster5 have outlined limitations associated with this method. For instance it cannot be used:

- Where the octave band spectrum differs from a spectrum where all frequency bands have approximately the same value
- Where there are significant variation in the sound pressure level over time
- When communication occurs in a highly reverberant environment
- Where speech is not articulated clearly (i.e. distorted)[5]

4.2.4 Masking and intelligibility

Noise interference with speaking is described by Berglund and Lindvall [1] as a masking process. The SNR will determine to what extent the signal can be perceived, but the more intense the level of masking, the greater percentage of speech sounds that are not discernible to the listener.[1]

In the usual discourse, most sentences can be understood reasonably well even when there are a large number of individual speech sounds masked.[1] This is because it is often not necessary to understand all words to extract the meaning. Certain words called key words are fundamental in establishing meaning. The technique of identifying the key words in a discourse for second language speakers and formulating the meaning without understanding everything that is said, is an important skill in second language acquisition when they do not have the same level of proficiency as a native speaker. The extra work in interpretation required to compensate for masking effects and /or lack of proficiency in the target language, adds additional strain on the listener. [1]

4.2.5 Estimating speech intelligibility

Many attempts have been made to develop a single index to indicate the degree of interference with speech perception of masking noise. Berglund and Linvall identified the three most common indices as: [1]

- Articulations index (AI)
- Speech interfere level (SIL)
- A-weighted sound pressure level.

A satisfactory speech intelligibility is defined as 70% intelligibility of monosyllables with an open test list.[11] This corresponds to an SNR with an articulation index of 0.45.[7]

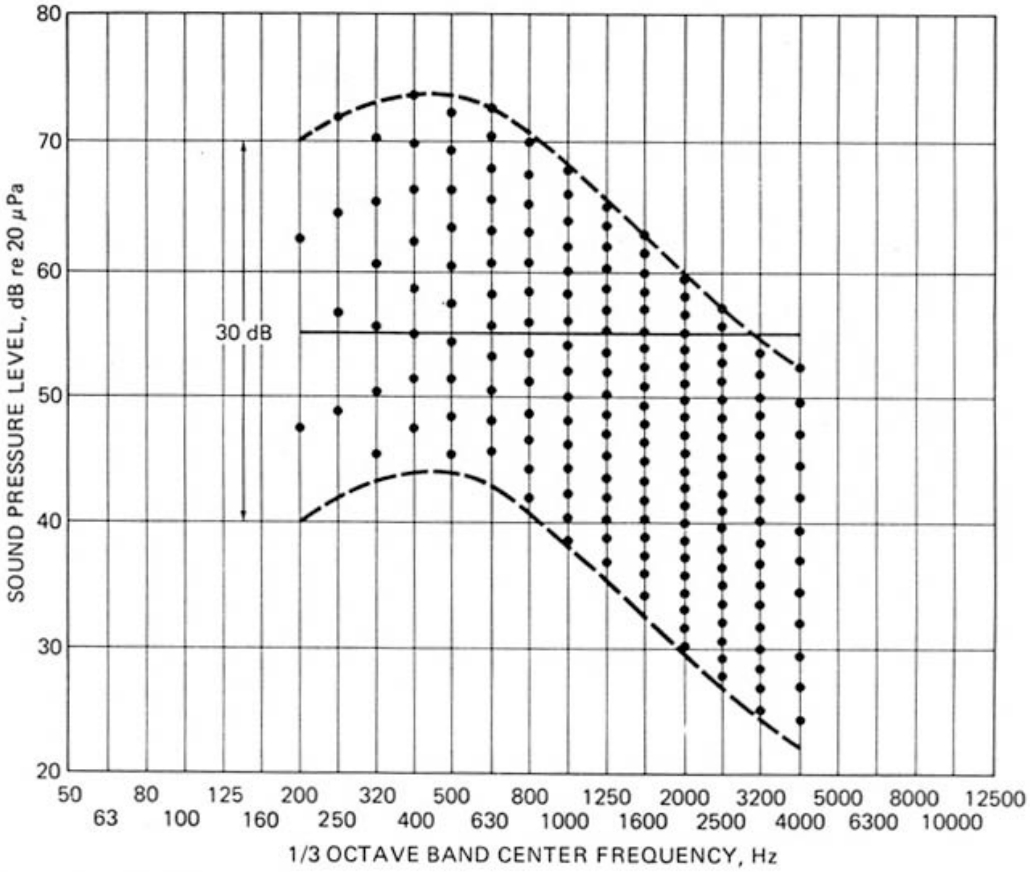
4.2.6 Articulation index.

The articulation index (AI) is the most complicated of all indices and for a time was rarely used.[1] It was developed by French and Steinberg[12] over 50 years ago and underwent further development by Kryter[13] and Cavanaugh et al.[14] It is based on the premise that some frequencies are more effective in masking speech than others. The frequencies outside the target range of 250-7000 Hz are omitted because they do not significantly contribute to speech intelligiblity.[1] The target frequency range is divided into 20 relatively narrow frequency bands, each of which contributes 5% to intelligibility. The AI for a particular noise is calculated by determining the difference in dB between the average speech level and ambient level in each band, and the results combined to give a single index between the numerical values of 0 and 1.0.[1,15]

May[16] and Kryter[17] have discussed the work of Cavanaugh et al[14] in some depth, as it appeared the most simple method known to calculate the articulation index at that time. In this work, the authors developed a nomograph (see Figure 4-3) to estimate the articulation index present in a room from speech uttered in an adjacent room. Here the 30 dB range between the upper and lower curves is where normal speech usually falls. Take the parts of speech falling on the ⅓ octave band of 500 Hz - these have a sound pressure level in the range of 43-73 dB (30 dB difference) for the great majority of people most of the time.[16]

The frequencies in the 1,500-3,000 Hz have been shown in studies to affect speech intelligibility more than the frequencies outside this range. The number of dots in the nomograph (Figure 4-3), reflect the relative importance to speech intelligibility of the various frequencies.

Figure 4-3 Curves to calculate articulation index.



Source: May [16]

The AI is calculated by:[16]

1. Plotting the ⅓ octave band frequency spectrum on the nomograph. (An example of 55 dB between 200 and 4,000 Hz is given).
2. Counting the number of dots between the spectrum plot and the upper curve (count from the top down to the ⅓ octave band frequency spectrum.
3. Dividing by 100 to obtain the AI.

As an example, a background noise has a flat ⅓ octave band spectrum of 55 dB between 200-4000 Hz. The number of dots between the spectrum line and the upper curve is 59, which divided by 100 gives approximately an AI of 0.6.

4.2.6.1 Interpretation of the articulation index

An intense background sound with a spectrum on or above the upper curve will have an AI ≅ 0 i.e. a large interference in speech. A sound having a spectrum lying on or below the lower curve will have an AI ≅ 1 i.e. implying little or no interference.[16] Table 4-2 given by May below, gives figures derived from everyday experience and doesn't allow for special conditions such as reverberation time (T_{60}), or aviation communication with trained operators using special language as examples. An acceptable AI in this case may be less than 0.3.[16]

Table 4-2 Interpretation of the articulation index

Interpretation	Very good communication	Good communication	Marginal but acceptable communication	Unsatisfactory communication
Articulation index AI	> 0.7	0.5-0.7	0.3 - 0.5	<0.3

Source: May[16]

In the case of the example given above, an, articulation index (AI) of 0.6 implies good communication.

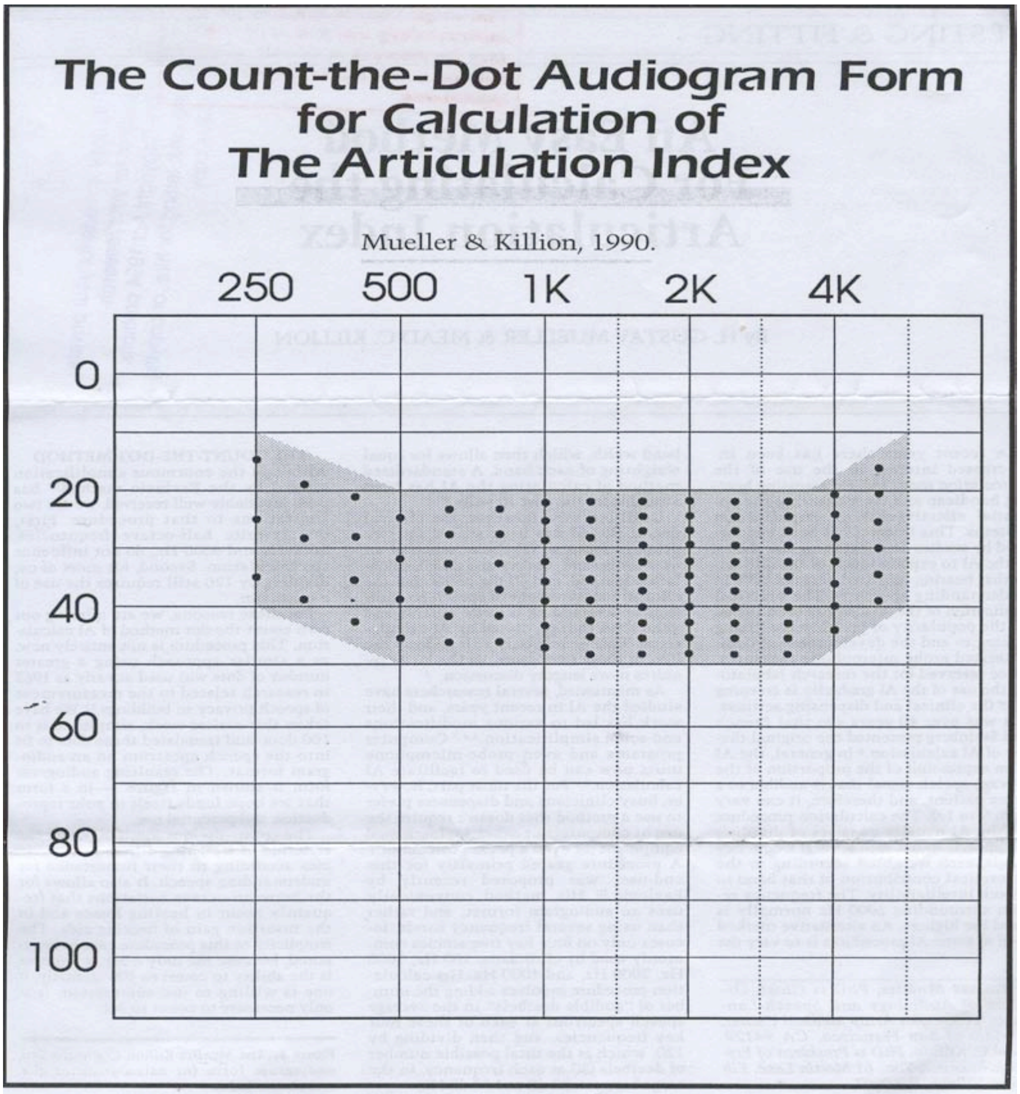
4.2.6.2 Recent developments in the articulation index

In recent years, there has been an increased interest in the articulation index and its movement from the research laboratory into clinical audiology. Its use in clinical settings has been hampered by the lack of easily understood calculations and also the belief that clinical measurement of speech recognition/understanding was more reliable than the use of AI calculations.[15] A convenient procedure developed by Pavlovic[18] used a 'count-the-dot' procedure on an audiogram format and focused on the 4 main frequencies 500, 1000, 2000, 4,000 Hz. It involved adding the number of 'audible decibels' in the 4 frequencies and then dividing by 120 (30 decibels in the 20 - 50 dB range for each frequency). While Mueller and Killon acknowledged the enormous simplicity of the Pavlovic method when compared to earlier procedures, they proposed the following 2 limiting factors.[15]

1. The half octave frequencies of 3,000 and 6,000 Hz are omitted.
2. Even though the arithmetic is simple, it still requires a calculator.

Mueller and Killon[15] modified the method devised by Cavanough et al[14] (described above) and produced their own simplified **'count-the-dot'** method with 100 dots for ease of use as shown in Figure 4-4. According to the authors this method meets the requirements of weighting different frequencies according to speech and allows for between octave variations that frequently occur in hearing loss and in insertion gain of hearing aides. It is also the easiest and most straight-forward method proposed to date.

Figure 4-4 The simplified method for calculating the articulation index



Source: Mueller and Killon[15]

The articulation index has 3 potentially important uses in the fitting of hearing aides.[15]

- Prediction of the patient's deficit (unaided) in normal level conversational speech
- Prediction of the benefit of a specific hearing aid
- Comparison of potential benefits of one hearing aid to another

The Mueller and Killon method has become a valuable assessment tool in audiology. It is widely used in clinical practice and is promoted in audiology practice manuals and texts.

In the case of an unaided audiogram (without hearing aids), the pure tone thresholds are plotted in the normal way on the audiogram. The dots occurring below the plot are those audible to the patient and these are counted and divided by 100. If 40 dots are counted below the plot, this results in an articulation index of 0.4.

4.2.7 Speech interference level (SIL)

The speech interference level was developed as a simple derivative of the articulation index.[1,16] It uses octave rather than ⅓ octave analysis of background noise.
The SIL changed with the application of the internationally adopted octave bands and became known as the preferred speech interference level (PSIL).[16]

The PSIL was the arithmetic mean of the sound pressure level in the 3 octave bands centred on 500, 1000, 2000 Hz. However the PSIL was never standardized and in 1977, the American National Standards Institute standardized the speech interference level.[19] This was the same as the PSIL with the addition of the frequencies centred on 4000 Hz. At present, the American National Standards Institute has recommended a speech interference level centred on frequencies 500, 1000, 2,000, 4000 Hz as providing the best estimate of masking noise. This is often abbreviated to SIL (0.5, 1.0, 2.0, 4.0).[1]

Lazarus[7] described the simplified prerequisites for the SIL method as:

- The speech level at 1 metre distances ($L_{SA,1m}$) is determined by the vocal effect. The speech level can be determined by the sound pressure level at the position of the speaker.
- Sound propagation corresponds to that of the free field.
- The sound level determines the speech interference level or the approximate A-weighted sound level.
- The relationship between the speech interference level and distance between speaker and recipient is defined by a given speech intelligibility or signal-to-noise ratio.
- A higher signal to noise ratio must be used for higher vocal effect because speech intelligibility decreases at higher speech levels due to distortions and vocal strain. The necessary signal-to-noise ratios for the higher vocal effects are given in Table 4-3 (below).

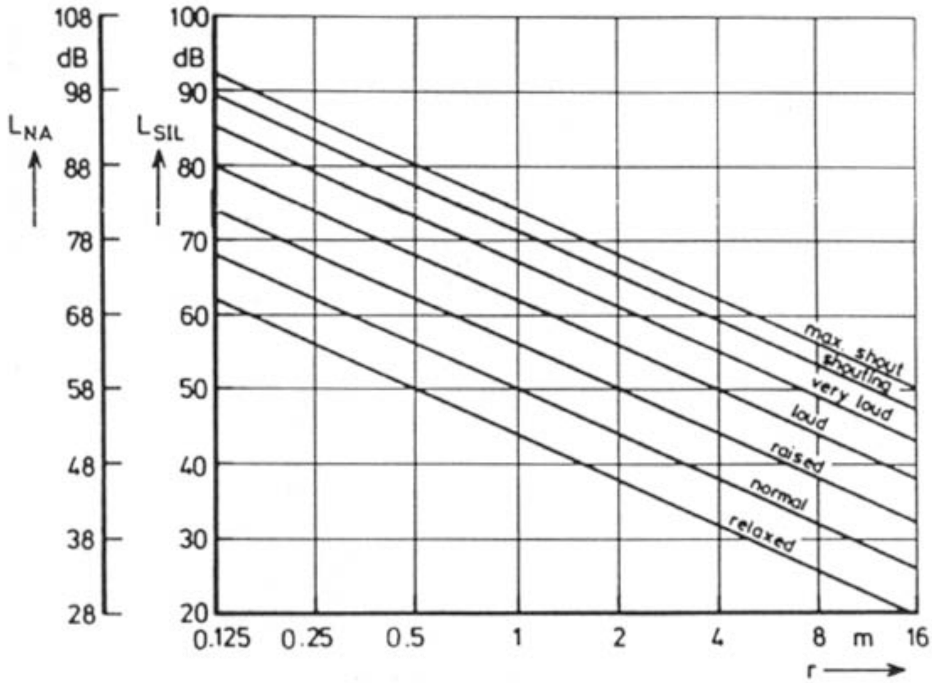
Table 4-3 Necessary signal-to-noise ratios for different vocal effects

Vocal effect	Signal-to-noise ratio (SNR) (dB)
Very loud	3
Shout	5
Maximum	8

Source: Lazarus[7]

The time-average sound level is used for fluctuating sound. The A-weighted sound level is used as an estimation value for the speech interference level (L_{SIL}). The A-weighted sound level approximates the speech-interference level L_{SIL}+ 8 dB for most sounds as shown in Figure 4-5 below:

Figure 4-5 Relationship of speech interference level to distance and vocal effect in the free field.



SIL-r-diagram: The relationship between noise level (LSIL, LNA) and the speaker-listener distance (r) for a satisfactory speech intelligibility for the vocal effort: relaxed to maximal shouting (normal vocal effort is LSA,1m = 60 dB). Satisfactory speech intelligibility means that for the vocal effort relaxed to loud, AI = 0.45 or LSNA = 3 dB and, for the vocal effort very loud, shout, maximal shout LSNA = 3, 5, and 8 dB

Source: Lazarus[7], Berglund and Lindvall[1]

Figure 4-5 (above) shows the relationship between the speech interference level (L_{SIL}) /A-weighted noise level (L_{NA}) and the speaker-listener distance (r) for satisfactory speech intelligibility for a vocal effect: relaxed to maximum shouting. The normal vocal effect is a speech level at 1 M ($L_{SA,1M}$) = 60 dB.

Satisfactory speech intelligibility means that for the vocal effect relaxed to loud, the articulation index (AI) = 0.45 or the SNR = 3 dB. For the higher vocal effects to achieve satisfactory speech intelligibility, the signal-to-noise ratios are given in Table 4-3 (above).

There have been some changes made to the speech interference level with some minor adjustments. Kryter[17] gave the speech interference levels of steady continuous noise at which reliable communication can just be perceived (face-to-face). These were based on the original pre-standardized SILs. Studies have found that the standardized SILs are approximately 1 dB higher than the original SIL and 2 dB lower than the PSILs, which is well within the margin of error of sound level measurements. However it is reasonable to correct the original SILs as given in Kryter to standardized SILs which are given in Table 4-4 based on the following criteria:[19]

- Original SIL + 1 dB = Standardized SIL
- The standardized SILs are approximately 2dB lower than the PSILs

Table 4-4 Standardized speech interference levels of steady continuous noise at which just reliable communication can occur.

	Speech interference level (standardized)			
Separation distance	Normal effort	Raised	Very loud	Shouting
0.15m	*72	78	84	90
0.3m	66	72	78	84
0.6m	60	66	72	78
1.2m	54	60	66	72
1.8m	50	56	62	68
3.7m	44	50	56	62

* The PSIL = 74 i.e. 2 dB higher than the standardized SIL as explained above.

Adapted from Kryter[17] and May[16]

May[16] has suggested a correction for adult females where 5 dB is deduced for females (and possibly children). As the preferred speech interference levels are approximately 2 dB higher than the standardised figures, it is reasonable to assume the same deduction of 5 dB for the standardized speech interference levels (Table 4-4), due to the obvious level of uncertainty in such perceived measurements.

May[16] also indicates an approximate relationship between the preferred speech interference level (PSIL) and most other sounds other than speech. The background noise is approximately equal to the PSIL + 7dB. This varies slightly for what Lazarus[7] and Levitt and Webster[5] have proposed, where the (standardized) L_{SIL} + 8 dB approximates the level of A-frequency weighted background noise. This means that with a SIL of 70 dB, the level of other competing noise is likely to be in the region of 78 dB.

May[16] gave an example of this usage but used what is now described as the non-standardized 3-band procedure[5] based on the PSIL which excluded the 4000 Hz frequency band. If this method is to be used, Levitt and Webster have instructed that the frequencies must be included as shown to avoid confusion. SIL (0.5, 1, 2). The standardized 4-band method includes the 4000 Hz band). Both methods are demonstrated in the worked example (adapted from May) below:

Determine if a noise is acceptable for speech on a bus if the octave band analysis of noise received at a passenger's ear on public transport is as follows:

Octave-band centre frequencies (Hz)	125	250	500	1000	2000	4000
Sound pressure level (dB)	90	87	80^{*+}	75^{*+}	70^{*+}	67*

Determine if this spectrum is acceptable for speech?

Answer using the Standardized SIL (4-band) method:

- Ignore frequencies outside 500 – 4000 Hz target range.
- Average the sound pressure levels* in the target range.

i.e. SIL = $(\frac{80+75+70+67}{4}) = 73\,dB$

Answer using the SIL (0.5,1,2) (3 band) method

- Ignore frequencies outside 500 - 2000Hz target range
- Average the sound pressure levels^{+} in the target range.

ie SIL (0.5,1,2) = $(\frac{80+75+70}{3}) = 75 dB$

If on a bus or train, we would expect to be able to talk in a normal voice to people one seat away (< 1metre). At 0.6 metres, the SIL = 60 dB for a man and (60-5) = 55 dB for a woman/child (assuming the same correction for SIL as for PSIL). Since the calculated SIL of 73 dB [or SIL (0.5,1,2) of 75 dB], both exceed the tabulated values of 60 dB in Table 4-4 (and 55 dB when corrected for females), this sound is unacceptably loud for close conversation.[16]

Lazarus[7] described the different ways the response function of the room can influence the speech sound, the equivalent noise ratio and therefore the speech intelligibility. These are:

- The influence of reverberation on speech and therefore intelligibility increases with the distance between speaker and listener.
- A reverberation time of no more than 0.5 seconds can slightly improve speech intelligibly for those with normal hearing but greater reverberation times decrease intelligibility.

Work has been done to compare speech intelligibly measurements in rooms using the three procedures, articulation index, speech transmission index and A-weighted signal-to-noise ratio. Rooms including classrooms with different reverberation times and signal receiver distances were used. Statistical analysis of all three procedures showed them to be relatively close in prediction of speech intelligibility.[20, 21]

There is no simple formula for predicting the relationships for communication indoors. Figure 4-5 (above) represents relationships in the free field (outdoors) with the application of the inverse square law. Berglund and Lindvall[1] indicate that Figure 4-5 can be used to determine permissible noise levels for a specific distance up to 2 metres and as an estimate up to 8 metres if the reverberation time is lower than 2 seconds. Standards can also be set on the basis of average sound pressure levels found to be acceptable in similar settings from past experience.[1]

4.2.8 Speech transmission index (STI)

This is a complicated model, which has a similar concept to the articulation index but takes both background noise and reverberation into account and can therefore be used as a model to evaluate speech communication indoors. Like the articulation index, it has a single index with a numerical value between 0 and 1.0.[1,2] The STI is based on the principle that a transmitted signal (m=1) is smoothed or modulated across a room, and when it reaches the listener, it will have a decreased modulation (m<1).[7]

Levitt and Webster gave the following key assumptions underlying the STI:[5]

- The effects of reverberation on speech intelligibility can be specified in terms of equivalent background noise.
- This equivalent background noise can be added to the actual background noise for obtaining the combined effect of background noise and reverberation on speech intelligibility.

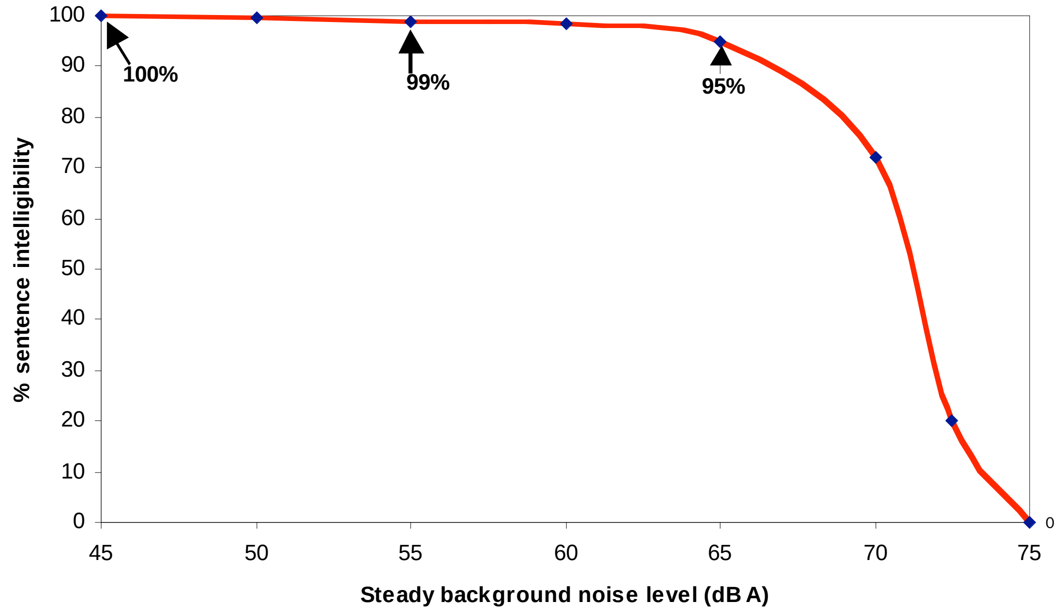
Berglund and Lindvall[1] describe the STI model as utilising a model transfer function (MTF), which quantifies the extent to which speech intensity fluctuations are preserved in masking noise and reverberation when transmitted from the speaker to listener.

Due to the complexity of this procedure, a simplified version known as the rapid speech transmission index (RASTI) has been developed which uses a reduced number of modulation frequencies and octave bands.

4.2.8.1 Estimation of speech intelligibility in a typical domestic setting.

The Office of Noise Abatement Control (USEPA) has given an estimation of sentence intelligibility at distances greater than 1 metre in acoustical conditions typical of a domestic living room with varying levels of background noise (see Figure 4-6 below). To achieve the desired 100% intelligibility for this environment, an A-frequency weighted background noise level of 45 dB or less is required.[1]

Figure 4-6 Normal voice intelligibly in relation to steady background noise levels in typical domestic living room environment.



Source: Berglund and Lindvall[1] and USEPA[22]

4.2.8.2 Communication evaluation

Lazarus[7] describes the various conditions for the evaluation of necessary speech communication for communication partners or a certain activity. These are:

1. The frequency of speech communication
2. The necessity of speech communication
3. The minimal speech intelligibility or the strain on the listener
4. The acceptable vocal effort or the strain on the speaker
5. The distance between the speaker and listener

Frequency and necessity of speech communication is the result of different conditions in communication situations e.g. homes, workplaces, shopping malls etc. These are the physical properties and human parameters, which influence the speech intelligibility and quality of the speech communication.

Lazarus[7] has cited studies, which show that as the noise increases, it can not only affect the listener, but the speaker as well. The state of communication partners varies in noise but is also subject to the type of activity. As the speaker becomes more hindered, annoyed and strained, so the listener becomes more confused, distracted and over-exerted. In an experimental study in which subjects were presented speech material at different noise levels and signal to noise ratios, it was shown that annoyance can vary with not only the noise intensity but the signal to noise ratio or the speech intelligibility. The type of spoken speech also determines the listener's annoyance in understanding speech at the same sound level for speech and noise. Lazarus[7] summarised the following factors, which determine annoyance during communication. These are:

- Speaker's vocal effect
- Signal-to-noise ratio at the listener's position
- Noise level
- Speech quality (prosody, vocal effect) at the listener's position

4.3 Summary

Speech intelligibility is a complex but inexact science relying on human subjective evaluations and variations. It is, however, a critical parameter in the evaluation of communication assistive technology such as assistive listening devices for the hearing impaired or sound-field systems to improve signal-to-noise ratios in school classrooms. The subjectivity of this phenomenon can be demonstrated with the variations proposed by individual authors of the speech communication and intelligibility indices such as the articulation index, the speech interference level and the speech transmission index. Such difficulties are common in parameters involving human subjective assessment such as the unpleasantness or offensiveness of an odour.

The dedicated efforts of a number of authors to develop the articulation index have resulted in an excellent, easy-to-use and practical tool in clinical audiology. More work following this example is warranted on the speech interference level and the speech transmission index. If progress in development of a simple method or instrument can be achieved for the speech transmission index, it would have the potential to become an invaluable tool in the installation and evaluation of classroom amplification technologies such as sound-field systems.

4.4 References

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5 The anatomy and physiology of the auditory system and processes

5.1 Introduction

Hearing and auditory processing are vital to the development of speech and communication in young children. A short discourse on the hearing process, its development in early childhood and conditions which affect hearing and processing of auditory information is therefore appropriate, although not an integral part of the research that forms this work.

5.2 The human ear

The ear is a very well developed and complex organ, which is capable of excellent discrimination over a wide range of frequencies and sound intensities. The reception and analysis is a complex process and is not yet completely understood. The ear consists of three major sections, the outer ear, the middle ear and inner ear.

5.2.1 The outer ear

This is the visible part made of a cartilaginous structure called the pinna or auricle, which is located on the side of the head. It is thought to enhance reception and provide some indication of direction of sound. On the other hand, the soft cartilage of the outer ear could also provide some cushioning effect of sound waves on impact and may mitigate the effects of loud noises. The pinna forms the opening of the oval shaped ear canal, which extends approximately 25mm to terminate at the eardrum (or tympanic membrane). The ear canal has a natural resonant frequency of approximately 3000 Hz, which increases the sensitivity in this region.[1,2,3] This could perhaps be explained as analogous to an organ pipe closed at one end. Closing the other end will create a new resonant frequency. For example when the ear is closed by application of headphones, a new resonant frequency will occur in the order of 6000Hz.[4]

5.2.2 The middle ear

The ear canal leads to the tympanic membrane (commonly known as the eardrum), which separates the outer ear from the middle ear. This latter section is an air filled cavity of about 2 cm^3 containing a chain of 3 articulated bones known as the ossicular chain or auditory ossicles, which transmit acoustic energy impinging on the tympanic membrane to the cochlea in the inner ear.[1,5] The malleus (or hammer) is the largest of the ossicles and attached to the tympanic membrane. The incus (anvil) is an interconnecting lever between the malleus and the stapes (stirrup). The smallest of the 3 ossicles, the stapes is connected to the incus by a ball and joint type socket (known as the incudostapedial joint). The base (or foot plate) rests in the oval window, the entrance to the cochlea of the inner ear, and is held in place by the annular ligament.[2,5] The 2 smallest muscles of the human body are the tensor tympani, (attached to the malleus) and the tensor stapedius (attached to the stapes). The muscles themselves are held in the bone and only the tendons are found in the middle ear space. These muscles are activated by any loud sound and provide a protective mechanism by causing a reflex contraction of the small muscles, which apply tension to the ossicular chain. This limits the motion to the oval window and therefore minimises damage.[1,2,3,5] As this aural reflex can provide protection for prolonged sounds, it will not provide protection for instantaneous sounds (peak levels) such as gunshot blasts as it takes a fraction of a second for activation. The eustachian tube connects the middle ear with the pharynx. It performs the following 3 functions:[3,6]

- To ventilate and equalise air pressure with that experienced by the outer ear
- Drain any secretions from the middle ear to the nose
- Prevent reflux of fluid into the middle ear

It is important to note that normal hearing relies on the middle ear being full of air and being well ventilated. In the case of upper respiratory infections, the eustachian tube may become blocked and this can lead to fluid in the middle ear cavity which decreases the elasticity of the eardrum and ossicles to vibrate freely and therefore inhibit the transmission of sound energy received at the ear. The eustachian tube is normally closed and opens when swallowing or yawning. In children, it does not function as efficiently as in adults. The support provided by the cartilage and bone is poor and the tensor veli palatini muscle, which opens the eustachian tube, is weaker than in adults. As the child develops, the eustachian tube function improves, resulting in less middle ear infections in older children and adults.[7]

5.2.3 The inner ear

The inner ear (also called the labyrinth due to its complicated shape) is comprised of a complex system of fluid filled cavities positioned deep in the temporal bone and located behind the eye socket (see Figure 5-1a).[8] The bony labyrinth is a system of channels winding their way through the bone with distinct regions or cavities including the cochlea and 3 semicircular canals positioned at right angles to each other. The semicircular canals are part of the body's balancing system.[3,8] The bony labyrinth is filled with perilymph, which is connected to and similar in composition to the cerebrospinal fluid.[8,9] The membranous labyrinth is a continuous series of membrane sacs contained within the bony labyrinth and floats in the perilymph. It bounds an extracellular fluid space, called the endolymphatic space (ELS), which contains the endolymph, a fluid of unique ionic composition.[8,9] Unlike some other non-mammalian species, the endolymphatic space is entirely bounded by cells, with no forms of direct communication with the perilymph.[9]

The cochlea is of a snail-like configuration of 2½ turns coiled around a central bone pillar also carrying nerve fibres. If unwound, it would be about 35mm in length. The cochlea houses the organ of Corti, which is the receptor organ for hearing. It acts as a transducer, converting mechanical vibrations into neural impulses, which are then transmitted to the brain. It is split in a longitudinal manner into two fluid filled cavities.[3,8] The cochlear duct and spiral lamina divide the cavity of the bony cochlea into 3 separate scala (chambers), the scala vestibuli (SV), the scala media (SM) and scala tympani (ST).[8,9]

The scala vestibuli is part of the bony labyrinth and filled with perilymph. It lies superior to the scala media and the oval window is located at its base. The scala media is also known as the cochlear duct and endolymphatic space as it is filled with endolymph. The two chambers are separated by Reissner's (or the vestibular) membrane. The external wall of the scala media, the stria vascularis, is made up of rich vascularised mucosa that secretes endolymph. The scala media contains the organ of Corti. The scala tympani is part of the bony labyrinth (like the scala vestibuli). It contains perilymph and lies inferior to the cochlear duct.[8] The scala tympani and scala vestibuli are in contact (or in communication) through the region known as the helicotrema, which is located at the cochlear apex. The basilar membrane of the organ of Corti separates this chamber from the scala media.[5,8] (see Figure 5-1 page 5-6).

5.2.3.1 Characteristics of inner ear fluids

Salt[9] has given the following chemical composition of inner ear fluids in Table 5-1 (below).

Table 5-1 Chemical fluid composition of the inner ear

Cations (mmol/L)	ST perilymph	SV perilymph	CSF	Cochlear endolymph	Saccular endolymph	ELS endolymph
Na^+	149	140	146	1	3	108
K^+	3.7	8	3.2	158	150	14
Ca^{2+}	0.7	0.6	1.2	0.02	0.09	0.47
Anions (mmol/L)						
Cl^-	127	125	131	136	119	98
HCO^-	19	18	19	21	-	-
Others						
pH	7.3	7.3	7.3	7.4		
E^0 (mV)	0	5	0	85	5	13
mOsm/ kg H_20	293	294	-	304	-	-

Source : Salt[9]

Key

ST	=	scala tympani
SV	=	scala vestibuli
CSF	=	cerebrospinal fluid
ELS	=	endolymphatic sac
E^0	=	electrical potential
mOsm/kg H_2O	=	osmolarity (see 1.3 Glossary)
Cl^-	=	chloride ion
HCO^-	=	bicarbonate ion
K^+	=	potassium ion
Ca^{2+}	=	calcium ion

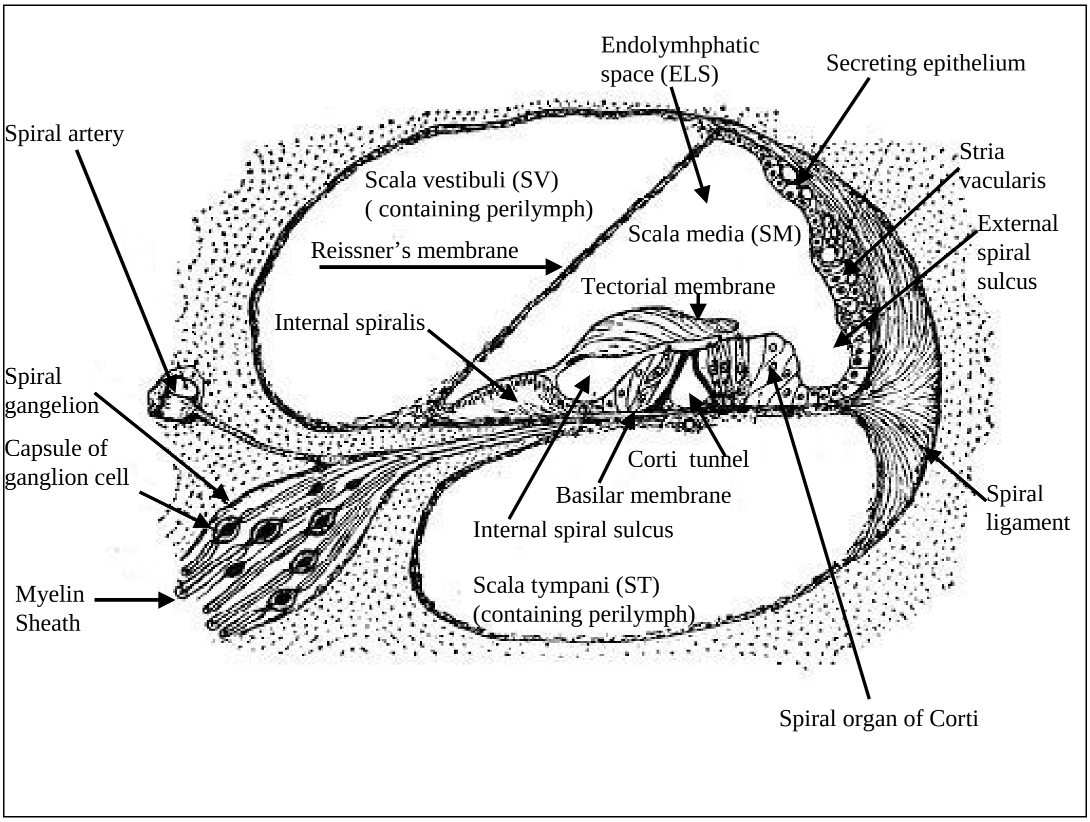
As can be seen from the above table, the perilymph has a similar ionic composition to other extracellular fluids with Na^+, the predominant cation having concentrations of approximately 148 mmol/L (scala tympani) and 140 mmol/L (scala vestibuli). However the K^+ concentration, although comparatively low, is higher in the scala vestibuli (8.0 mmol/L) than the perilymph in the scala tympani (3.7 mmol/L) and the cerebrospinal fluid (3.2 mmol/L). The ionic composition of Na^+ in the perilymph, is slightly less in the scala vestibuli (140 mmol/L), than in the scala tympani (149 mmol/L).[9] Salt[9] suggests that the composition of perilymph is not homogenous throughout the cochlea. The osmolarity of perilymph has been found to be similar to that of blood plasma suggesting that perilymph is close to osmotic equilibrium with blood.

When compared to other extracellular fluids, the ionic composition of the endolymph is quite unique with K^+ the dominant cation in the order of 150 mmol /L. By comparison, the Ca^{2+} (0.02 mmol/L) and Na^+ (1 mmol/L) compositions are low.

An endocochlear potential (a positive voltage of approximately 80-100 mV) is present in the cochlea, which varies from the base to apex. How this unique characteristic originated is not known although there have been a number of hypotheses proposed. The complicated electrical mechanism of the cochlea is still not fully understood although a model proposed by Davis[10] in 1965 is still accepted as a simple explanation. The endocochlear potential and the resting potential of the hair cells results in a standing current through the sensory cells. The hair cells act as a variable resistor which changes with the movement of the basilar membrane. Resistance increases with displacement of the basilar membrane towards the scala tympani and decreases with displacement towards the scala vestibuli.

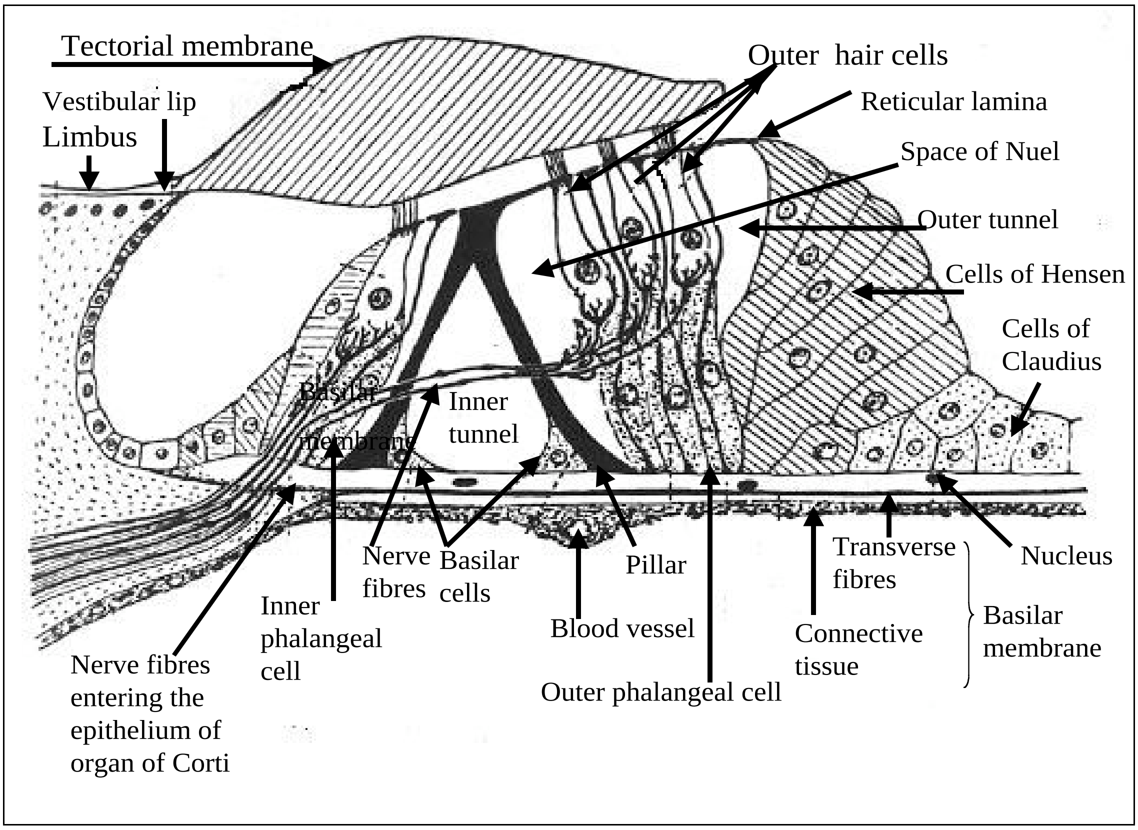
Figure 5-1 The inner ear

(a) Cross section of the inner ear showing the scala and organ of Corti



Source: Sataloff and Sataloff[6]

(b) Cross section of the organ of Corti



Source: Sataloff and Sataloff[6]

5.2.3.2 The organ of Corti

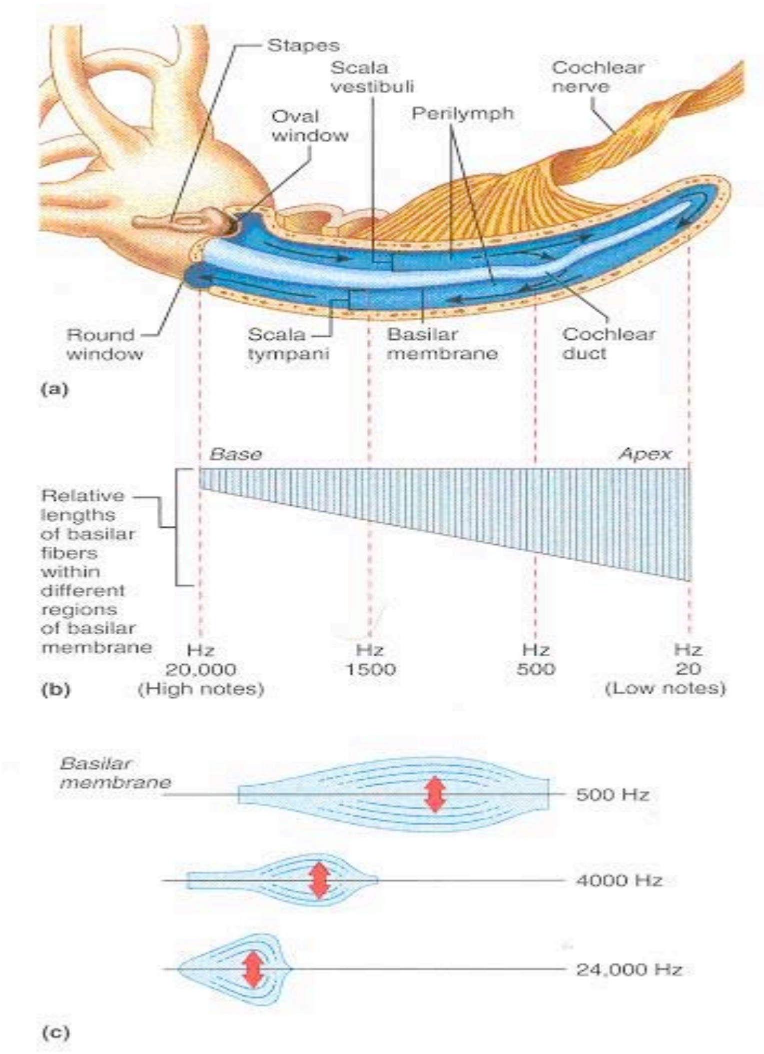
The organ of Corti, a complex and intricate structure, contains a large number of minute hair cells (estimated between 15,000 – 30,000 in number) along with supporting cells resting on a fibrous flexible structure known as the basilar membrane. This runs the length of the cochlea.[1,3,7,8,9] The excitation mechanism is activated hydraulically by acoustical energy. Because the tympanic membrane is about 20 times as large as the oval window, the force exerted hydraulically on the oval window is about 20 times that exerted acoustically on the tympanic membrane. As the stapes is set into motion, it sets the perilymph into a similar back and forth movement.[8] As fluids cannot be compressed, it is the membrane of the round window which bulges laterally into the middle ear cavity. This causes the basal part of the cochlea to oscillate sending a pressure wave towards the helicotrema. Low frequency sounds of less than 20 Hz create a pressure wave that moves right through the cochlea i.e. through the scala vestibuli, around the helicotrema and through the scala tympani back towards the round window. These sounds are below the threshold of hearing and do not appear to activate the organ of

Corti.[8] However sound waves of a higher frequency are transmitted along the cochlear duct into the perilymph of the scala tympani. Salt[9] suggests that the cochlear tunnel, which is filled with the cortilymph, acts as a low pass filter attenuating the cerebrospinal fluid pressure fluctuations for frequencies above 20 Hz. Pressure fluctuations below 20 Hz are thought to not be attenuated by the cochlear tunnel.[9] After the pressure passes through Reissner's membrane, this sets the entire basilar membrane into motion with maximum displacement occurring in different sections of the basilar membrane according to the frequency of the pressure wave, when the fibres in question strike their reasonant frequency as shown in Figure 5-2 (below). The hair cells nearer the oval window resonate in response to the higher frequencies to cause the greatest excitation at the end of the duct, whereas at the apical end of the coil, lower frequencies resonate to cause the greatest stimulation.[1,8] Sound signals are therefore processed by the resonance of the basilar membrane before reaching the cochlear hair receptors. Along the length of the cochlea runs the cochlear nerve which is a division of the vestibulocochlear (VIII cranial) nerve.[8] The movement causes electrochemical changes in the hair cells from which impulses to the brain are initiated. From here, the auditory nerve transmits the neural impulses to the brain, which processes the information to produce the hearing sensation.[1,3] It is worth noting that the reason why noise-induced hearing loss typically occurs in the 3,000 – 6,000 Hz frequency range is probably due to this being the resonant frequency of the ear canal.[4] If the ear is occluded, the resonant frequency is in the 6,000 Hz range.

Salt[9] described the hairs or stereocilia of the hair cells as containing actin filaments for stiffening and being linked by tip links (very fine fibres). These protrude into the endolymph comprised predominantly of the K^+ ion. When the hair cells are deflected by the flexing of the basilar membrane, the cilia are bent towards the longest cilium, which applies tension to tip links, resulting in an opening of cation channels in the adjacent shorter sterocilla. An inward K^+ and Ca^{2+} current occurs with a graded depolaristion. When the cilia are bent away from the tallest cilium, the tip links relax and the ion channels close producing a graded hyperpolarisation. Depolarisation with the rise of intracellular Ca^{2+} is thought to increase the neurotransmitter substance causing afferent fibres to increase the number of impulses to the brain. Hyperpolarisation produces the opposite effect with the reduction of intracellular Ca^{2+} and a resultant decrease of number of impulses to the brain.[9]

There still appears considerable uncertainty in the complex transducer mechanism of the cochlea by which neural impulses are generated.

Figure 5-2 Activation of cochlear hair cells



Source: Marieb and Hoehn [8]

The cochlea (specifically the outer hair cells as they expand and contract) is able to produce low intensity sounds called otoacoustic emissions (OAEs). Four types are produced:[11]

- Spontaneous otoacoustic emissions are spontaneous sounds emitted without any acoustic stimulus

- Transient (evoked) otoacoustic emissions are sounds emitted due to acoustic stimuli of very short duration
- Distortion product otoacoustic emissions are the sounds emitted due to a stimulus by sounds of different frequencies
- Sustained frequency otoacoustic emissions are sounds emitted in response to a continuous tone

While the response is emitted from the cochlea, the middle and outer ear must be able to transmit the sound (in reverse) back to the OAE recording microphone and so OAEs can only measure the peripheral auditory system (outer, middle and inner ear). OAEs are often used as a neonatal screening tool to test the presence/absence of cochlear function.[11] In addition this clinical technique is used for children too young to participate in conventional hearing tests.

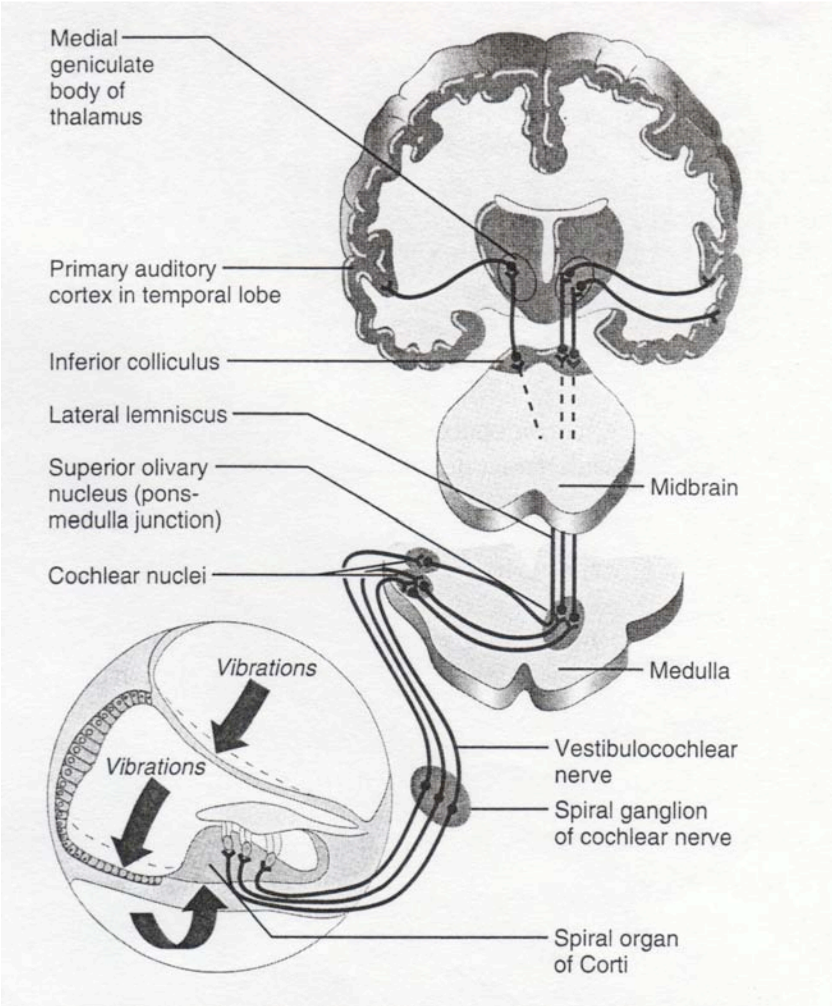
5.2.3.3 The neuro-auditory pathway

Marieb and Hoehn[8] described the auditory pathway to the brain. There are several ascending auditory pathways to the brain involving various brain stem nuclei but the most important pathway for the impulses produced by the organ of Corti ascend via the spiral ganglion (see Figure 5-3) to the cochlear nuclei in the medulla. From here the impulses pass to the superior olivary nucleus and through the lateral lemniscal tract to the auditory reflex centre of the mid brain known as the inferior colliculus. From there the impulses pass to the auditory cortex in the temporal lobe through relays in the medical geniculate body in the thalamus. Impulses also pass from the inferior colliculus to the superior colliculus in the midbrain. These colliculi acting together produce the reflexes to sound such as the startle reflex and head turning.[8]

5.2.3.4 Processing of auditory signals.

Marieb and Hoehn[8] suggested that one of the most remarkable aspects of auditory processing is the ability to distinguish important sounds from what can be described as auditory jumble of extraneous sound. If the discrimination of sound waves is sufficient, two distinct tones can be heard. They described the analytical power of the auditory cortex as being so great that it allows listeners to detect single instruments in an orchestra.[8]

Figure 5-3 Neuro –auditory pathway from the organ of Corti to the auditory cortex and temporal lobe of the brain.(Right ear pathway shown)



Source: Marieb and Hoehn (2007)[8]

Auditory processing is a complex function with some cortical cells depolarising at the beginning of a tone sounding with others depolarising at the tone end. There are cells which seem to depolarise continuously with some having higher thresholds than others. Figure 5-3 (above) shows the pathway from the right ear where the signal is processed by both sides of the auditory cortex of the brain but that the signal processing in this case will be stronger in the left side of the cortex (described as the contralateral auditory pathway.[8] It is now recognised that a range of auditory disabilities include processing problems in which the brain processes auditory signals differently from the norm. Such conditions include autistic spectrum disorders and central auditory processing disorder, where there is reduced ability from normal processing to regulate the sensation produced by auditory signals, such as speech from other extraneous noise.

5.3 The development of the ear in the foetus

Moore describes the formation of the human ear in some detail.[12] According to him, the internal ear is the first to appear in the fourth week of gestation with a thickened plate of surface ectoderm, the otic placode forms on each side of the developing hindbrain. Both placodes invaginate and sink below the surface ectoderm into the mesenchyme to form the otic pit. The otocyst loses its connection with the surface ectoderm and a hollow diverticulum grows out from the otocyst, which lengthens to form the endolymphatic duct and sac. Two distinct regions appear - the utricular portion and the ventral portion. The endolymphatic duct rises from the utricular portion. Three flat diverticual grow out and then the central portions of the walls of these fuse and disappear. The unfused portions become the semicircular canals. The ampullae develop at one end of the canal. Sensory nerve endings become distinct in the ampullae, utricle and saccule. The cochlear duct grows from the ventral saccular portion of the otocyst and coils to form the cochlea. The organ of Corti differentiates from cells in the cochlear duct. Ganlion cells of the VIII cranial nerve migrate along coils of the cochlea and form the cochlear ganglion from which nerve processes grow to the organ of Corti. A cartilaginous otic capsule forms from the mesenchyme around the otocyst. The membranous labyrinth enlarges and vacuoles form in the otic capsule which develops into perilymphatic space, which itself develops into the scala tympani and scala vestibuli. The otic capsule converts into the bony labyrinth of the internal ear.[12]

5.3.1 Formation of the middle ear

It would seem that the middle ear develops from the tubotympanic recess. The distal portion expands into the tympanic cavity and the proximal portion becomes the eustachian tube. With the tympanic cavity expansion, the endodermal epithelium gradually envelops the middle ear ossicles (malleus, incus and stapes), their tendons, ligaments and chorda tympanic nerve. The muscle attached to the malleus, known as the tensor tympani is formed from the first branchial arch and the tensor stapedius from the second branchial arch.[12] The development of the external, middle and inner ear all overlap.

5.3.2 Formation of the external ear

The external acoustic meatus develops from the first branchial groove. This funnel shaped tube extends inward to become the meatal plug and late in gestation this forms a cavity to become the inner part of the external acoustic meatus (ear canal). The tympanic membrane begins to form from the first branchial or closing membrane, which separates the first branchial groove and pharyngeal pouch. The mesenchyme extends between the closing membrane and this becomes the fibrous stratum of the tympanic membrane. The auricle develops from the 6 swellings around the first branchial groove called the auricular hillocks. The auricle grows with the lobule being the last part to develop. The auricles begin to develop in the upper part of the neck region. As the mandible develops the ears move to the side of the head and to the same level as the eyes.[12] The innervation of the ectodermal cells by a branch of the vagal nerve was able to discern minute pressure changes which were useful for hunting. This indicated an evolutionary vestige.[13]

5.3.3 Chronological development of the ear

There appears some uncertainty over the time periods of development during gestation although the development of the cochlea is usually complete by the end of the second trimester of gestation. Lerner[14] indicates that while a new born's ear looks like that of a fully developed adult, research is continuing to determine when the ear completes development and takes on a full adult-like function. As this could extend into puberty, it would be prudent to limit a child's exposure to noise well below that considered an acceptable risk for adults. An important aspect of foetal development of the ear relates to delay in development of teratogenic influences with effects such as balancing and walking.[13]

5.4 The hearing process by air conduction.

Air conduction is the most usual process by which the auditory function occurs. Sound waves enter the ear via the pinna and travel down the ear canal to vibrate the eardrum. From here the ossicular chain transfers the vibrations to the cochlea, which converts these into neural impulses, which are transmitted to the brain for processing via the auditory nerve.

5.5 The hearing process by bone conduction

Acoustic energy is also transmitted by the cranial bones to the inner ear, a process known as bone conduction. One hears their own voice partly by this method. When the sound is sufficiently intense, a small fraction of acoustic energy in the air is converted to solid-bone vibration in the skull. The sound may also be received by conduction through the bone structure from other parts of the body. The same patterns of vibration as in air conduction are set up along the basilar membrane. It is worthy to note that pathways other than air conduction are important considerations in evaluating hearing protecting devices such as ear plugs or earmuffs.[1]

5.6 Auditory response

The ear is a sophisticated and well-developed organ being able to process information over a surprisingly wide range of sound pressure and frequencies. Figure 5-4 (below) shows the levels in which useful acoustic responses are received, which levels usually include speech and music. The auditory sensation range stretches from low sound pressure levels at the threshold of hearing to high sound pressure levels in the regions of discomfort and pain.[1]

5.7 Threshold of hearing

This is the minimum sound pressure level for a specific sound that can evoke an auditory response. It depends on the following factors: [1]

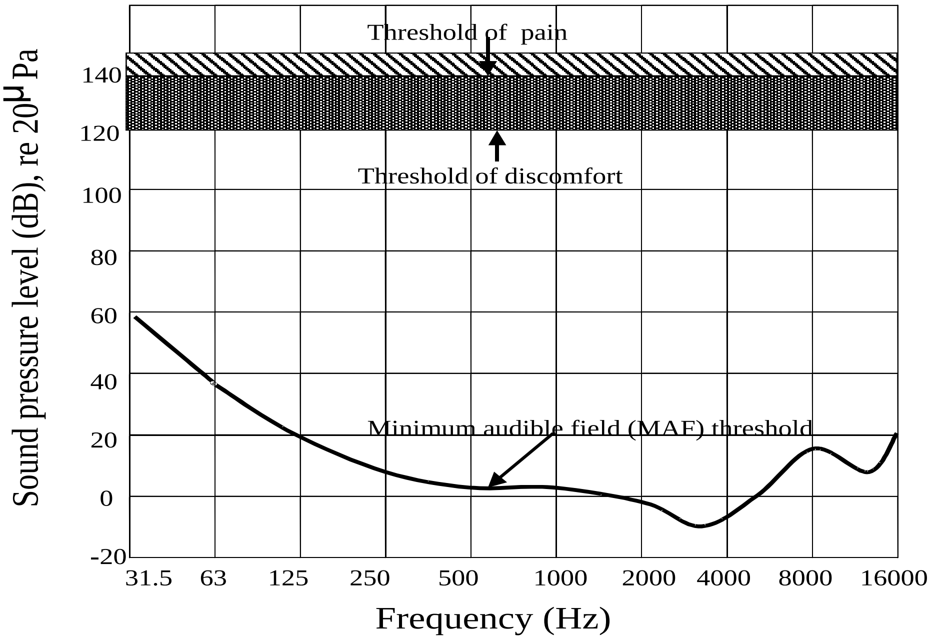
- Sound characteristics (e.g. frequency components)
- How it is presented to the listener (i.e. headphones, loudspeaker in free space etc.)
- The point at which the sound pressure level is measured. This can be at the entrance to the ear canal or in the free field in the absence of the listener

If a threshold value is measured in the presence of noise, it is termed a masked threshold. It depends on the background noise level.[1]

5.7.1 Minimum audible field (MAF) threshold.

Small and Gales[1] have defined the minimum audible field threshold (MAF) as the sound pressure level of threshold of hearing for young adults with normal hearing, measured in the free field at the position of the listeners. This is shown in Figure 5-4.

Figure 5-4 Auditory sensation area



Adapted from Small and Gales [2]

MAF has been developed from measurements of persons with normal hearing who have not suffered any ear problems and from young persons aged 18-25 years where presbycusis (loss of hearing with age) is not an issue. This is important in noise control because many people are exposed to noise in largely free field conditions. There is considerable variation in hearing sensitivity among normal listeners and it can even be different for each ear of an individual.[2]

5.7.2 Thresholds of discomfort and pain.

At sound pressure levels above 120 dB, the average listener experiences discomfort, and at about 140 dB, the listener experiences pain. It is likely that children will experience discomfort and pain at lower levels than adults. The World Health Organization recommended that in the case of children sound pressure levels should never exceed 120 dB.[15] A study by Freeman et al[16] examined long term noise exposure on the developing and developed ear in laboratory rats. The study was based on the auditory development of the rat and designed to model the human foetal development of the ear. Anaesthetised young rat pups and mature adults were exposed to long-term continuous white noise (15 days at 12 hours daily continual exposure) of varying intensity. The effects were measured by electrophysiological and histological examinations. The authors observed greater histological damage to the cochlea of young immature rats (especially in the apical region of the basilar membrane) when compared to adult rats. They did not find a lower threshold function or greater susceptibly for noise-induced hearing loss in young rats when compared to adult rats by electrophysiological examination (otoacoustic emissions, and auditory brain stem evaluation). The observed histological damage could suggest long term rather than immediate effects on auditory function, as the onset of noise-induced hearing loss typically occurs gradually. A study on the long-term effects of such observed histological damage to the developing ear would be of benefit.

5.8 Discussion

A detailed discourse of current knowledge is a vital component of this work especially in the early development and status of the human hearing mechanism and auditory processing systems so these can be directly related to the effects of the acoustic learning environments of young children. The importance of early detection of hearing deficits in new born babies has now been widely recognised in New Zealand with the introduction of the neo-natal hearing screening programme so that early intervention strategies can be implemented. Likewise early detection of conditions giving rise to auditory processing difficulties such as autism enable the child to receive early intervention and special education initiatives as soon as possible.

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6 Diseases, conditions and disorders giving rise to auditory function deficits.

6.1 Introduction

While the most familiar diseases and conditions affecting auditory function are those involving hearing loss, there is a wide range of other disorders including those on the autistic spectrum, attention deficit disorders, central auditory processing disorders, or any condition which impedes the person from receiving and processing auditory signals and information. The most common of these disorders have been summarised.

6.2 Hearing impairment and deafness

Hearing impairment and deafness usually involve a malfunction of the ear and auditory nerves as distinct from other auditory disorders, which include problems in processing aural information received at the ear. Hearing impairment or hearing loss can be defined as a reduction of hearing ability of variable cause, degree, duration and effect.[1]

One of the most common forms of hearing loss is that caused by prolonged exposure to excessive noise. This is commonly referred to as noise-induced hearing loss (NIHL) which is a sensorineural hearing loss usually of gradual onset and irreversible. NIHL usually results in the degeneration of the hair cells of the organ of Corti in the region of 4000-6,000 Hz. To make the diagnosis of noise-induced hearing loss, the New Zealand Department of Labour gives the following criteria:[2]

1. The shape of the hearing threshold curve should show a characteristic notch (or V shape) at 4,000-6,000 Hz with a recovery at high frequencies required. Because an audiogram does not match this pattern, noise-induced hearing loss cannot be excluded. As NIHL increases, the notch widens and is lost.

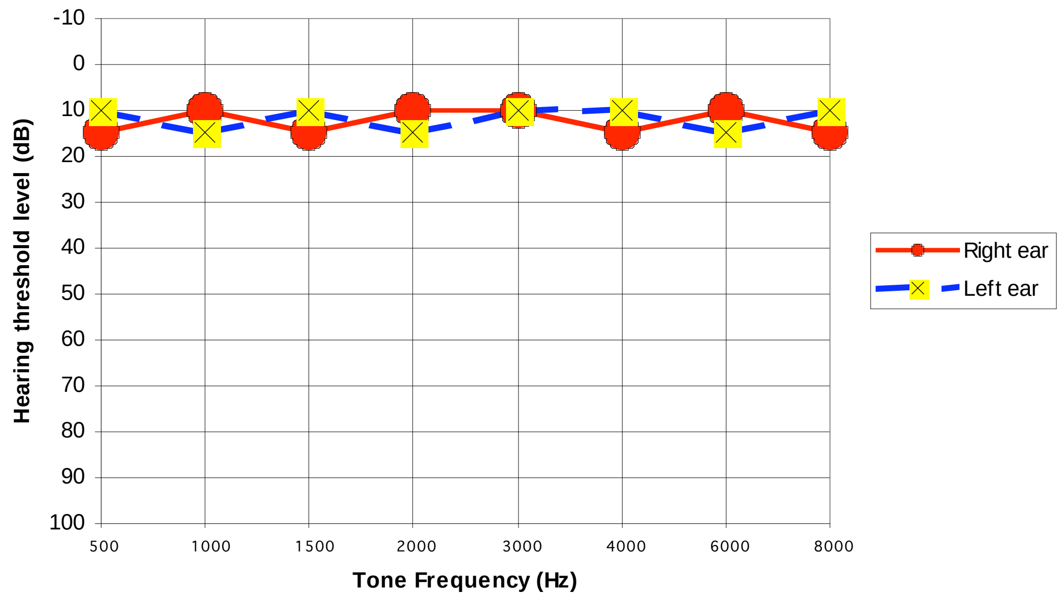
2. A symmetrical loss is expected in each ear or there should be an explanation on the basis of exposure history or other factors. A person involved in shooting or playing the violin where one ear is subjected to much higher levels of sound than the other, is one explanation for asymmetry.

3. For the purposes of formal notification, the audiogram must measure the magnitude of the hearing loss by noting the depth of the notch from an established baseline. The criteria adopted:
   - The threshold at 4,000 Hz is at least 30dB hearing loss; and
   - The 4000 Hz threshold is least 15 dB greater (worse) than the 2000 Hz threshold

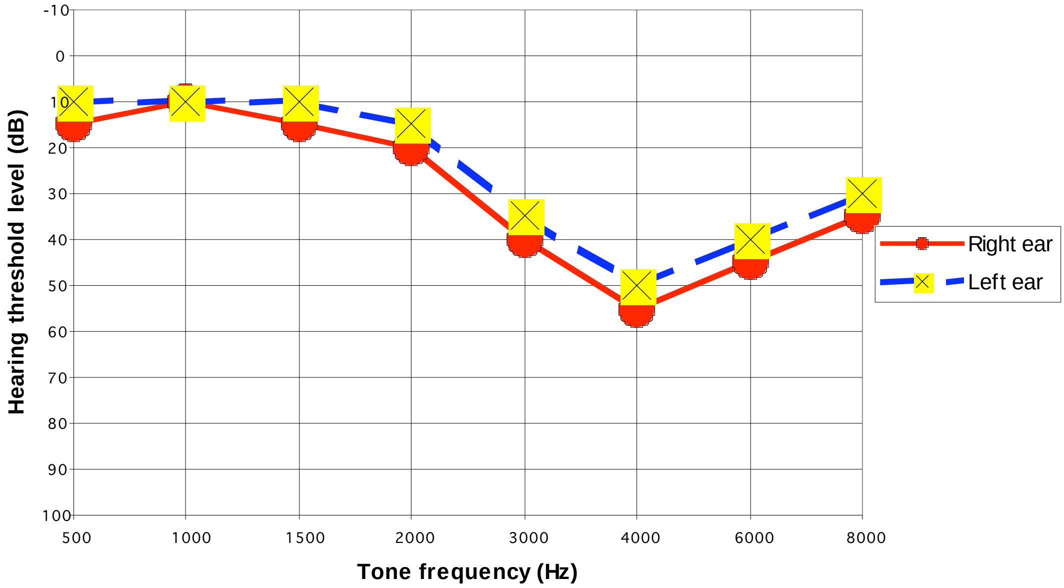
Typical audiograms are given below (Figures 6.1a, Figure 6.1b) for persons with normal hearing and noise-induced hearing loss.

Figure 6-1 Examples of typical audiograms

(a) An example of an audiogram within normal healthy range of hearing



(b) An audiogram of a person with noise-induced hearing loss



Source: Adapted from Dept of Labour[2]

Sensorineural hearing loss is usually permanent and occurs when either the inner ear or auditory nerve is damaged. It can have a severe effect on children, especially if it occurs at the pre-lingual stage of development.[1]

The main causes of deafness in pre-lingual young children are:[1]

- Hereditary deafness
- Congenital abnormalities
- Bacterial meningitis
- Rubella, cytomegalovirus and toxoplasmosis during the pregnancy of the mother
- Asphyxia at birth
- High levels of unconjugated bilirubin after birth (resulting in jaundice).

It is estimated that sensorineural hearing impairment affects about 0.2% of children and while it cannot always be prevented, it is essential that there is early detection and remedial action if the handicap is to be reduced.[1]

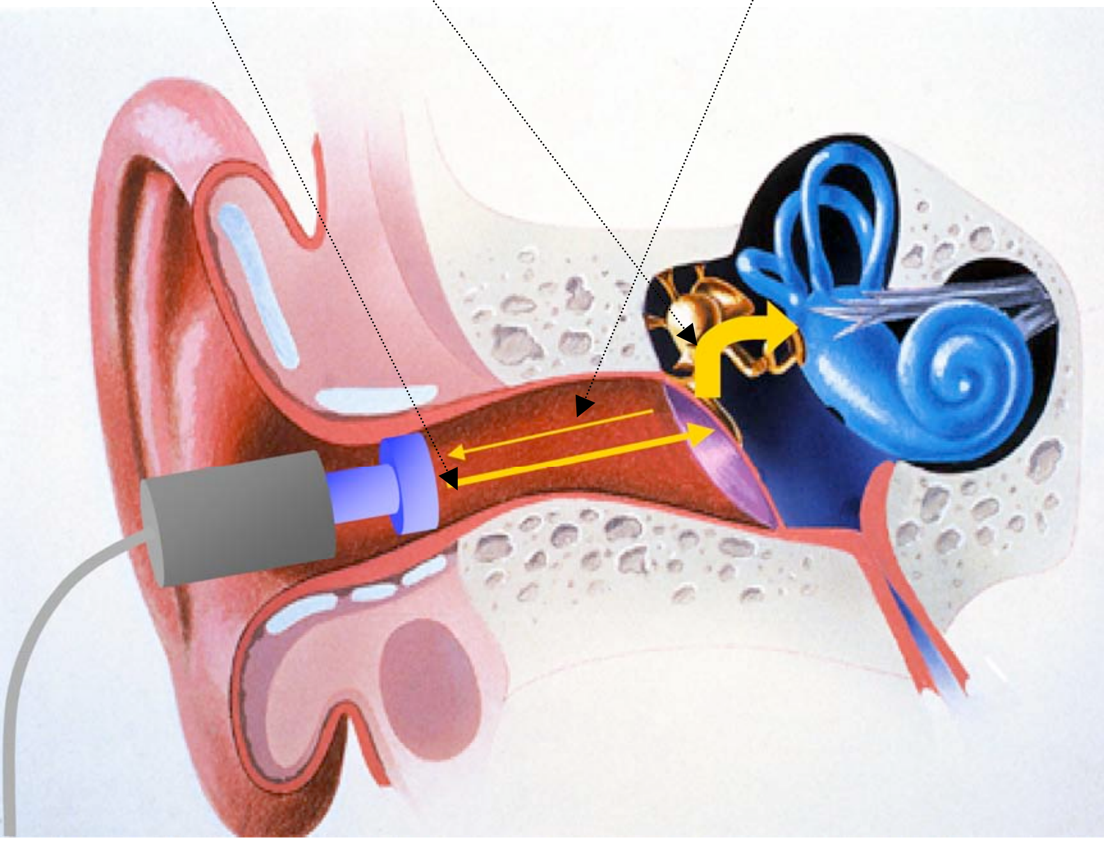
Conductive hearing loss is a form of hearing loss due to hereditary or congenital malformations of the middle ear structures, or inflammation of the middle ear. This may result in ruptured eardrums and the discharge of fluid in the middle ear, or blocked ear canals.[1] Middle ear inflammation and fluid are very common in early childhood but most cases of the condition or any associated hearing loss are not permanent. Persistent otitis media with effusion (commonly known as glue ear) can result in significant hearing loss and is therefore a major health concern. Section 6.3 (page 6-9) gives a detailed description of otits media infections.

6.2.1 Tympanometry

As it is often difficult to gain a routine reliable screening audiograms with young preschool children, tympanometry is now used as a screening tool to assess the condition of the middle ear. This is normal when the air pressure either side of the tympanic membrane is approximately equal to optimise the mobility of tympanic membrane and ossicles.[3]

The tympanometer (or impedance meter) is a hand held device, which measures the response of the middle ear to the sound energy applied and therefore provides quantitative information of the function and presence of fluid in the middle ear cavity.[3,4] It produces a sound stimulus in the ear canal at a frequency of 226 Hz, and a vacuum pump applies a range of positive and negative pressures in the ear canal and to the tympanic membrane. A probe is inserted which generates a tone as shown in Figure 6-2. A portion of the tone is reflected and some is admitted to the middle ear - a process known as static admittance, which is monitored continuously by a microphone in the probe tip itself. The remainder of the energy emitted by the tone probe (i.e. that which is reflected back) gives the static admittance of the ear, which depends on how well the middle ear is functioning.[3,4,5]

Figure 6-2 The insertion of the probe into the ear canal showing the probe tone being sent, admittance into the middle ear, and reflection back to the probe microphone.



Source: Fergusson[5]

Ferguson[5] and Hall & Mueller[6] described the 3 elements, which define the response to sound, which are:

- Spring (S): The elastic response of the tympanic and round window membranes, ligaments, middle ear muscles and air in the ear canal and middle ear space. This parameter is referred to as compliance.
- Mass (M): The mass or weight of the ossicles and the air in the middle ear mastoid cells.
- Friction (F): the energy loss through dissipation into heat and motion of molecules. This is referred to as conductance.

Tympanometry is a measure of the amount of probe tone admitted to the middle ear when ear canal pressure is varied. The admittance peaks when most of the tone probe enters the middle ear. This is called tympanic peak pressure (TPP), which approximates the middle ear pressure and whether the eustachian tube is functioning properly.[3,5]

The following useful data is given by a tympanogram:[4]

- Equivalent ear canal volume (the estimated volume of air in front of the probe) measured in millilitres (ml). It is abbreviated as Vea or ECV. This is often displayed on the right vertical axis of the tympanogram as shown in Figure 6-3 (below).
- Static admittance is the maximum compliance (or mobility) of the middle ear structures. The mobility of the tympanic membrane reaches its maximum when air pressures are equal on each side. The static admittance is measured in millilitres (ml) and is read from the vertical peak of the tracing on the left Y-axis. This represents the maximum acoustical energy absorbed by the middle ear.
- Tympanic peak pressure. This is indicated on the X-axis and is measured in dekapascals (daPa) or mm H_2O. (Note that 1 daPa =1.02 mm H_2O. Pa x10 = daPa). This parameter is an estimation of the middle ear pressure and is usually around zero for a normal ear. It is read from the X axis from the vertical peak of the tracing.
- Width of the tracing. This can be compared to the normal range for the age group. If a wide tracing is recorded with a normal peak height this has been reported as sensitive to middle ear disease, but not widely accepted by many authorities as a reliable diagnostic indicator. It may indicate the early stage of otitus media with effusion or near resolution.

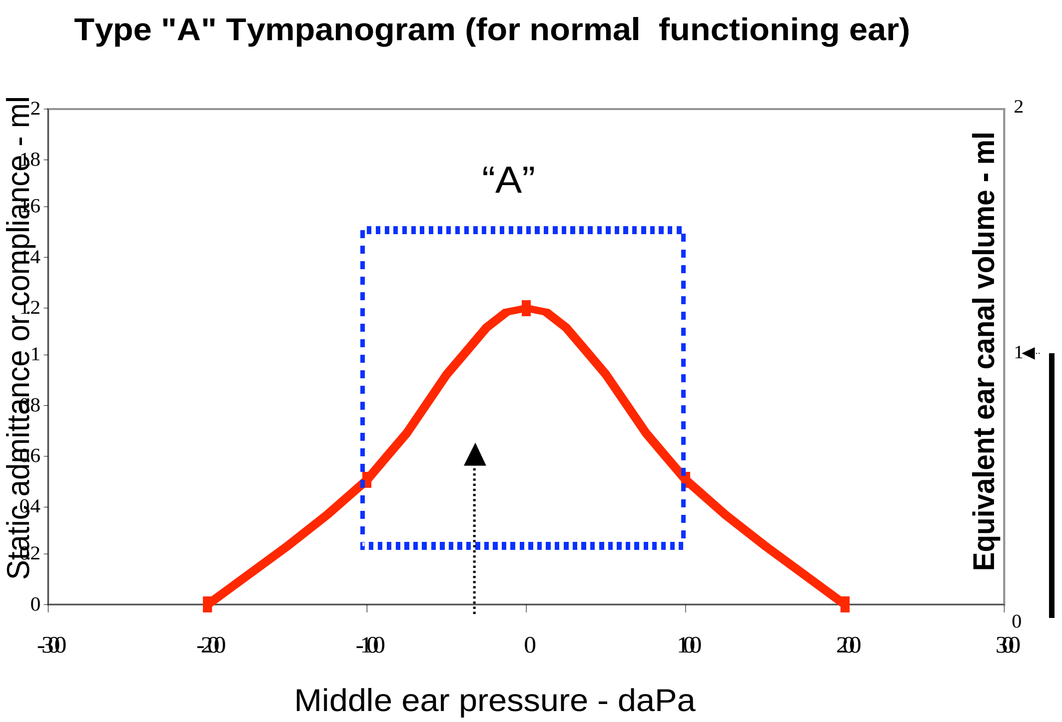
Figure 6-3 (below) gives the most common type tympanograms encountered with preschool chidlren.[3,4,5] These are described as follows:

- **Type A tympanogram:** In a normal functioning ear (shown by a), the normal range is within the boundaries of middle ear pressure (from -100 to +100 daPa and static admittance 0.3-1.5 ml).
- **Type C tympanogram:** The negative middle pressure is caused by oxygen and nitrogen being continually absorbed by the mucosal lining of the middle ear. If the eustachian tube is blocked, air is not admitted to the middle ear to replace that being absorbed. While this is common in children, it is not usually harmful

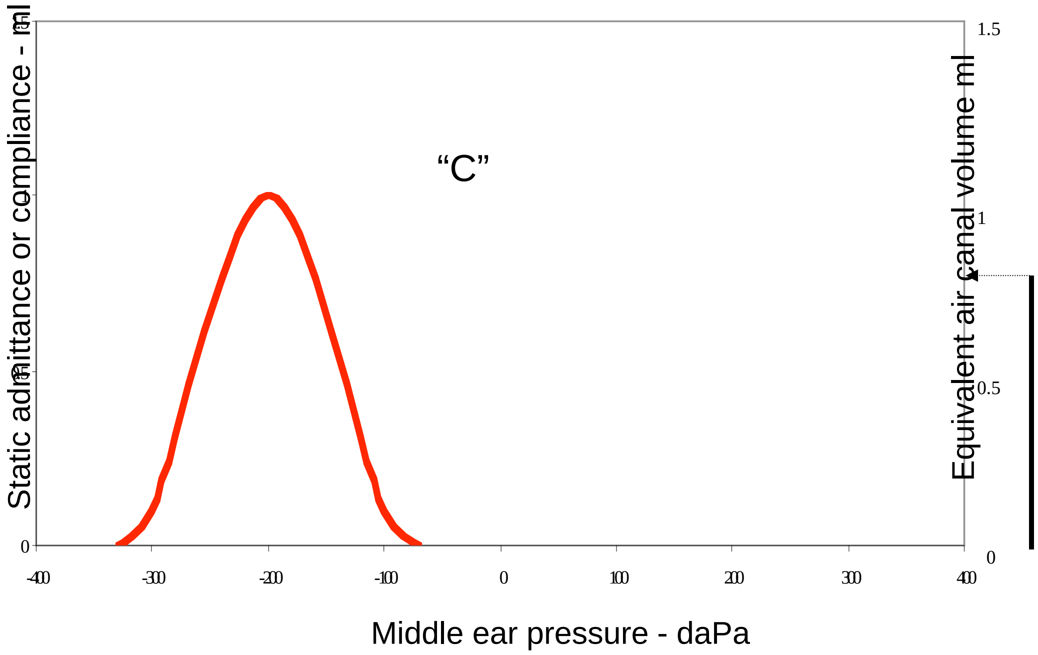
unless it persists, leading to retracted tympanic membranes and the resultant complications.

- **Type B/C tympanogram:** This occurs when a combination of air and fluid fills the middle ear. It is in transition between B and C tympanograms and at a stage before the middle ear is completely full of fluid.
- **Type B tympanogram:** When the middle ear is full of fluid, the tympanic membrane is unable to vibrate properly regardless of pressure, giving a flat recording. A low equivalent ear canal volume indicates partial ear occlusion with cerumen or incorrect fitting of the probe. It will also indicate effusion. If a high equivalent ear canal volume is recorded, this could mean perforation of the tympanic membrane.[4,5]

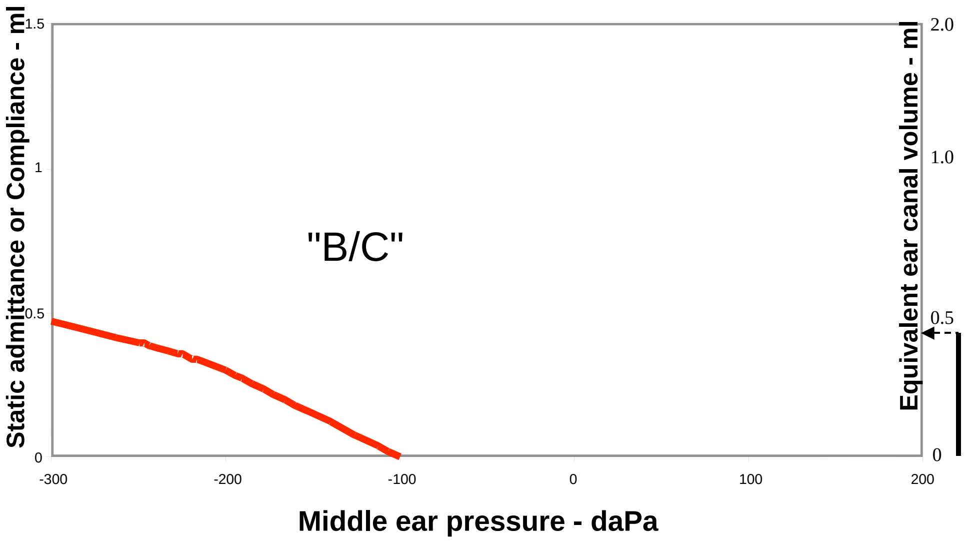
Figure 6-3 The most usual tympanograms Types, A, B, C and B/C[3,5]

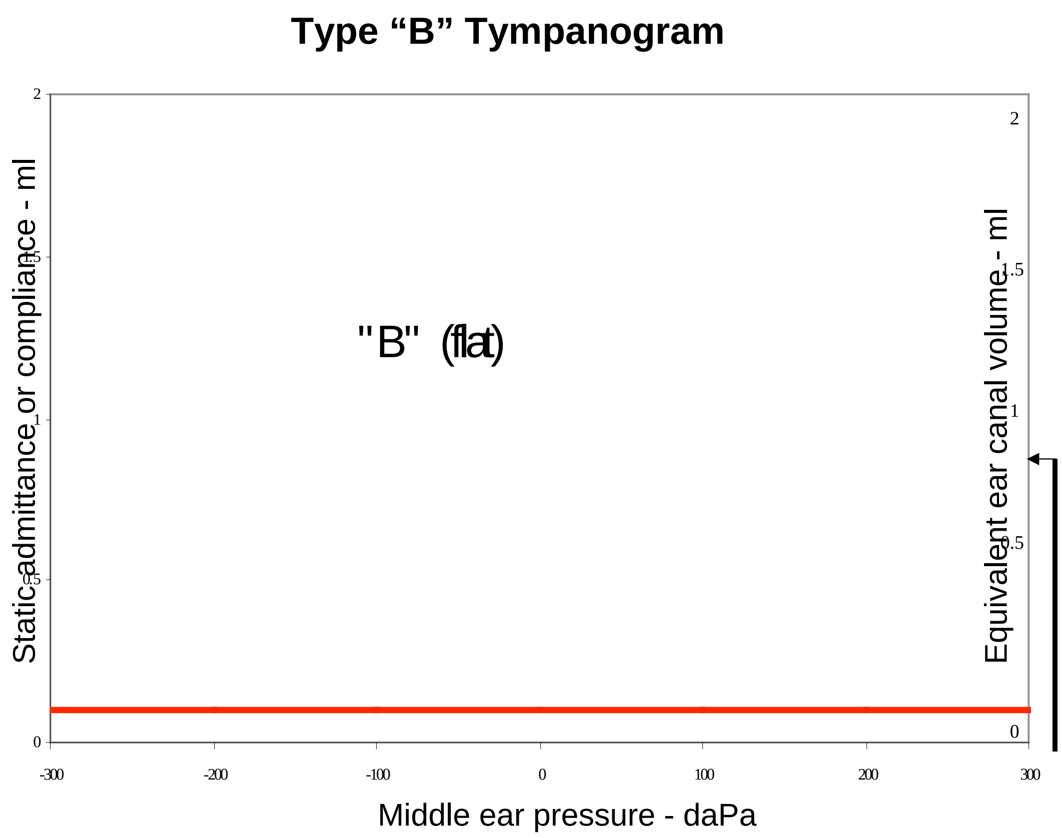


Type "C" Tympanogram



Type "B/C" Tympanogram





6.3 Otitis media with effusion (OME)

Otitus media with effusion (OME) or glue ear as it is commonly known has been identified as one of the most prevalent diseases of early childhood. It is called glue ear due to the glue like consistency of the discharge, which fills the middle ear cavity.[3,8] Wong[7] suggests that approximately 70% of children have at least one episode of OME and one third have suffered 3-4 more episodes by 3 years of age with the highest incidence in children aged 6 months to 2 years. Except for the time when children start school, where a small increase occurs, the incidence decreases and occurs infrequently in children over 7 years of age.

Otitus media with effusion has been described in a variety of ways and Wong gives the following standard terminology:[7]

- *Otitis media (OM)* — An inflammation of the middle ear without reference to aetiology or pathogenesis. This is a general term referring to inflammation (fluid and inflammation)
- *Acute otitis media (AOM)* — This is active infection of the middle ear with an inflamed eardrum. It is characterised by a rapid and short onset of signs and symptoms lasting 3 weeks approximately
- *Otitus media with effusion (OME).* — An inflammation of the middle ear in which a collection of fluid is present in the middle ear space. Fever is absent and ear discomfort is minimal
- *Chronic OME* — Middle ear effusion, which persists more than 3 months

Wong[7] describes the aetiology of acute otitis media as frequently caused by the microorganisms, 'streptococcus pneumoniae' and 'haemophilius influenzae'. The aetiology of the non-infectious type in not known but is often the result of blocked eustachian tubes from the oedema of upper respiratory infections, allergenic rhinitis (hay fever), or hypertrophic adenoids. Chronic OM is often an extension of AOM. OME is most likely associated with the common cold and other causes of nasal congestion. It can follow silently with little or no pain. [1,7]

Allen[3] reports that American Indian and Inuit children have high rates of otitis media whereas Afro-American children have low rates. Maori have approximately twice the rate of non-Maori. Australian Aboriginal children are known to have an extremely high rate. Allen[3] suggests that such different rates are due to racial factors affecting the shape and function of the eustachian tube, differences in response to infection, and social factors such as tobacco smoke and lack of breastfeeding in favour of bottle-feeding.

In 1995 the former Public Health Commission reported that approximately 9% of New Zealand 5 year old children are affected by persistent OME, with a higher prevalence among Maori and Pacific Island children.[1]

Children have poorly developed immune systems and often suffer from respiratory infections especially in their first 2 years of life. Infections are common in many children a few days before the onset of otitis media. The mucosal lining of the nasopharynx and eustachian tube swells to further impair its function. Children with high levels of contact with other children will have up to seven times the normal rate of OME due to the high levels of transmission among children. These include children in child care facilities and those from large families.[3]

Environmental factors have been implicated such as passive tobacco smoke, overcrowding, housing dampness, mould, mildew and allergens. Wong[7] suggests the theory that inhalation of smoke increases the risk of blocked eustachian tube by impairing mucociliary function causing congestion of the soft naso-pharyngeal tissues, or predisposing patients to upper respiratory infections. Most health authorities including the New Zealand Ministry of Health strongly recommend that parents or caregivers should never smoke near children.

A relationship has been established between the incidence of otitis media and feeding practices in infants. Infants, which are breastfed, have a 50-60% lower incidence of otitis media than those exclusively fed by bottle.[3,7] This is thought to protect infants from respiratory viruses and allergies with the presence of increased secretory immunoglobulin A (IgA) and limits the exposure of the eustachian tube and middle ear to pathogenic microorganisms and foreign proteins.[7] Reflux of milk into the eustachian tubes is less likely in breast-feeding due to the semi-vertical position of feeding when compared to how babies are normally bottle-fed.[7] Feeding a baby lying flat, with access to the bottle on demand, has been associated with a high incidence of OME and tooth decay. Therefore babies should be fed with the baby's head tilted upwards and not in the horizontal position.[3]

Allen describes other high risk groups such as children with cleft palate, that are prone to chronic OME due to the impaired muscular control of the eustachian tube. About half of children with Down syndrome are prone to chronic otitis media. Children with mid-facial abnormality are a high-risk group.[3]

If the eustachian tube is blocked, normal ear secretions are unable to drain down this tube and will build up filling the middle ear with fluid.[3] Intrinsic obstruction can be caused by infection or allergy while extrinsic obstruction is usually due to enlarged adenoids or nasopharyngeal tumours.[7] Obstruction results in a negative middle ear pressure and, if persistent, produces a middle ear effusion. Sustained negative pressure and impaired ciliary transport within the eustachian tube inhibits drainage. Contamination can also be caused by reflux, aspiration, or insufflation when crying, sneezing, nose blowing and swallowing with an obstructed nose. In the presence of middle ear effusion, goblet cell hyperplasia of the mucosal lining of the middle ear may result in the fluid becoming mucoid. Immunological reactions can occur resulting in effusion if bacteria are present.[3]

Wong described the factors predisposing infants and young children to the development of otitis media. These are:[7]

- The eustachian tubes are short, wide, straight and lie horizontally.
- The cartilage lining is undeveloped making the tubes more distensible and more likely to open inappropriately.
- Pharyngeal lymphoid tissue readily obstructs the eustachian tube opening in the nasopharynx.
- Immature humoral defence mechanisms increase the risk of infection.
- The lying down position of infants allows bottle fed fluid to collect in the pharyngeal cavity rather than draining away.

One of the most serious consequences of prolonged middle ear infection is hearing loss, although it is mild in nature. This is caused by negative middle ear pressure, effusion or damage to the tympanic membrane. The most serious consequence is the effect on speech development, language and cognition.[7] A number of recent studies are suggesting that hearing loss has a major impact on educational development and performance at school.[16]

Tympanosclerosis, or eardrum scarring, is often observed in children with middle ear inflammation, or those with repeated tympanoplasty replacement where hyaline material is deposited into the fibrous layer of the tympanic membrane. Eardrum perforation occurs often in acute otitis media and chronic ear disease.[7]

In adhesive otitis media (also known as glue ear), the mucous membrane thickens by proliferation of fibrous tissue, which fixes the ossicles and leads to hearing loss.[7]

Chronic suppurative otitis media is an inflammation of the middle ear and mastoid, resulting in perforation and discharge up to 6 weeks duration.[7]

Labyrinthitis is an infection of the inner ear.[7]

Although not common, cholesteatoma or chronic ear disease is a potentially serious and invasive consequence of otitis media with effusion.[7] This is caused by the fluid, which has been present for an extended period of time, being slowly reabsorbed. The tympanic membrane is drawn inwards under the negative pressure, which is formed in the middle ear cavity.[3] Retraction pockets form usually in the attic or top of the tympanic membrane, which can fill with fluid, keratin and bacteria, from which the cholesteatoma is formed. The fluid accumulates in the middle air cavity and as it grows in size, it corrodes everything in its path. It has the potential to destroy the middle or inner ear, depending on the direction of invasion. There is an unpleasant odorous discharge of a yellow-grey colour. The condition is often painful and results in permanent hearing loss of increasing severity. Treatment is by surgical removal of the cholesteatoma.[3,7]

As fluid accumulates in the middle ear chamber, pain occurs from pressure exerted. Infants become irritable, hold or pull their ears or roll their heads from side to side. High temperatures of 40^0C are common with enlargement of postauricular and cervical lymph glands.[7] Rhinorrhoea, vomiting, diarrhoea, respiratory and pharyngeal infections can occur with loss of appetite. Sucking or chewing can increase pain, and as pressure increases, it can cause the tympanic membrane to rupture. Wong[7] warns that, as this gives an immediate relief of pain, a decrease in body temperature and discharge from the ear canal, it could be interpreted by parents or caregivers that the child is now well and doesn't need medical attention. Severe pain or fever is often absent and the children may not appear ill. The ear feels full with popping feeling during swallowing. Chronic serious OM is the major cause of hearing loss in young children.[7]

6.3.1 Treatment and therapeutic management of acute otitis media

Antibiotics are the main form of treatment and therapy. A variety of antibiotics may be prescribed individually or in combination with amoxicillin, which is the antibiotic of choice. After antibiotic treatment, a further consultation to evaluate the effectiveness and to identify complications such as effusion or hearing impairment should be undertaken.[8] Wong[7] describes management of children with recurrent AOM to be frustrating, and therefore other therapies have been examined including chemoprophylaxis with long term antibiotic therapy, steroid use, immunotherapy, and surgery.

Where children have fluid that persists for months, the main goal of treatment or therapy is to maintain an aerated middle air, free of fluid with normal mucosa, and to therefore achieve normal hearing.[7,8] Wong[7] indicates that there seems considerable uncertainly in the acti-monicrobial and surgical management of otitis media. When medical interventions are unsuccessful, surgical management is often considered. Myringotomy with ventilation tubes (or grommets) is a surgical procedure effective for eliminating pain and hearing loss where there is no spontaneous perforation of the tympanic membrane. A small incision is made in the tympanic membrane to allow the accumulated fluid, which has accumulated in the middle air cavity, to be removed by suction. This procedure, allows the eustachian tube a period for recovery while the ventilation tubes take over the function of ventilating the middle ear cavity.[3,7,] A layer of keratin forms around the ventilation tube and after about a year, it will drop out as the tympanic membrane heals. While this is a relatively straight-forward surgical procedure, ventilation tubes may become plugged and often require reinsertion.[7] Allen describes other complications which include:[3]

- Scarring of the tympanic membrane (tympanosclerosis) which does not usually affect hearing.

- Infection from soapy water entering the middle ear cavity when hair washing or bathing. Water loses its surface tension with soap, aiding penetration through the ventilation tube into the middle ear cavity.
- Infection from water entry when diving below the surface of water.
- Ventilation tubes dropping into the middle ear cavity. This requires surgical removal under anaesthetic.

Wong indicates that while most cases of otitis media can be resolved, conductive hearing loss is considered the most common complication, which can extend from nothing to a severe loss. Sensorineural loss can also occur in serious cases due to toxic products of fluids into the cochlea through to the tympanic membrane. The longer the fluid is present the greater the potential for this loss.[7]

In New Zealand, OM is identified as the major cause of hearing loss among children. Maori and Pacific Island children are the most vulnerable with considerably higher rates than other groups. The Public Health Commission[1] reported in 1994 that of new entrants attending school, 13.9% Maori and 14.7% Pacific Island children failed hearing tests, compared with 7.2% of other children. At that time, the rates of smoking among Maori were reported at about 44% and among Maori women at the peak of child-rearing age (15-34 years old) to be 64%. Overseas studies have suggested that as many as 33% of OME cases can be attributed to tobacco smoke. Ethnicity and lower socio-economic status have been implicated as causal factors in OME, although it is subject to debate. A survey conducted in 1975, showed Maori of a higher socio-economic group to have less ear disease than a comparable European (Caucasian) group.[9, 10] This perhaps lends weight to the argument that socio-economic factors and practices such as smoking and lack of breastfeeding in favour of bottle feeding are the major factors in determining the extent of OME. New-born babies are obligatory nasal breathers so the positioning for feedings is very important.[11] Health authorities report that OME occurs more frequently in winter and has been associated with attendance at early childhood centres, possibly because of the higher risk of common cold and upper respiratory tract infections.

Access to appropriate prevention and treatment services for high risk children and their families is essential as the non treatment of acute and chronic OME can lead to major health and developmental problems in terms of learning achievement and behavioural problems in education.[10]

Health authorities stress the importance of detecting hearing complications and/or loss as soon as possible.

6.4 Children at-risk from exposure to noise

Hearing impairment or other auditory function deficit in young children can have a major effect on their development of speech and communication, resulting in a detrimental effect on the ability to learn effectively at school. This is likely to have major consequences for the individual and population as a whole. As a result of research carried out over the 2 previous decades, the former Public Health Commission reported in 1995 that hearing loss affects 6-10% of children in New Zealand.[1]

Hearing loss is well recognised to have significant implications. A mild conductive hearing loss affects speech and language development, and in turn also impacts on other areas of development.[12] The trend to include children with auditory deficits in mainstream classrooms has resulted in an increased emphasis on the child's ability to listen and learn in this predominantly audio-verbal environment, where 50-90% of information is disseminated through the auditory channel.[12]

According to Flexer[13] and Bennetts and Flynn[12] a major premise of the education system is undermined if a child cannot hear or process the teacher’s voice clearly and consistently for the following reasons:

- Hearing loss can be described as an invisible filter that distorts, smears or eliminates incoming sounds.
- A child is expected to hear and comprehend sounds from a distance.

A comprehensive study in New Zealand has found that classroom noise presents a major concern for teachers and pupils.[14,15] Modern teaching practices, classroom construction and means of ventilation all contribute to the number of children unable to comprehend the teacher’s voice. Nelson and Soli[16] have suggested that the recent trends in learning often involve collaborative interaction of multiple minds and tools as much as individual possession of information.[17] This all amounts to increased activity and noise levels,[14] which have the potential to be particularly serious for children experiencing auditory function deficit.[16] Noise in the classrooms can only exacerbate their ability to comprehend and process verbal communication with other children and instructions from the teacher.

Children with auditory function deficit are potentially failing to learn to their maximum potential because of noise levels generated in classrooms. The combination of auditory function deficit and poor classroom acoustics cause significant learning problems.[16] The effects of noise and associated conditions on the ability of children to learn effectively in typical classroom environments are now the subject of increasing concern. The International Institute of Noise Control Engineering (I-INCE) on the advice of the World Health Organization, has established an international working party, which includes New Zealand, to evaluate noise and reverberation control for schoolrooms.[18]

While the detrimental effects of noise in classroom situations are not limited to children experiencing disability, those with a disability that affects their processing of speech and verbal communication could be extremely vulnerable.[16] The auditory function deficits in question include hearing impairment, autistic spectrum disorders, Down syndrome and attention-deficit disorders (ADD/ADHD). For children prone to middle ear infections which result in hearing loss, and those with other auditory functions deficits which affect their ability to receive and process verbal information, the effects of poor classroom acoustics has become of great concern.[12]

The Ministry of Health[53] reports that in the last two decades major advances have been made in child and adolescent mental health with the clear diagnostic classification of various problems and behaviours. There has been improvement on the previously large and ill-defined categories, as well as a major paradigm shift from perceiving these children's problems as a reflection of parenting and other environmental/ecological factors, towards recognised disorders with a contributing genetic or biological cause. The Ministry of Health states that these diagnostic categories have been subject to increasing scientific scrutiny as to reliability, validity and implications for aetiology, treatment and prognosis.[53] Autistic spectrum disorders and attention-deficit/ hyperactivity disorder (ADHD) rank among those of greatest interest and concern.

6.5 Pervasive development disability (PDD)

The Diagnostic and Statistical Manual of Disorders (DSM)[19] describes the criteria for a group of severe early developmental disorders, which are characterized by delays and distortions in multiple areas of development. These include social skills, cognition and communication. This category includes autistic spectrum disorders (ASD), Asperger's syndrome, Rett's disorder and pervasive developmental disability not otherwise specified (PDD-NOS).[20]

6.5.1 Autistic spectrum disorder (ASD)

Autistic spectrum disorders includes a continuum of disorders ranging from severe or classical autism, also known as Kanner's syndrome, to the more able or high functioning autism and Asperger's syndrome. There is no known cause of the physical disorder and no biological markers have been identified**.** Autistic spectrum disorders are diagnosed by clinical observation and not by laboratory tests. Autism is considered a neurological and genetic life-long disorder that causes discrepancies in the way information is processed.[20] It is characterised by interlinking deficits in social imagination, social communication, social interaction and occupational function.[21,22] According to Janzen,[20] this affects the ability to understand and use language to communicate with people, understand and relate in typical ways to people, understand events and objects in the environment and understand or respond to sensory stimuli. Janzen[20] attempted to define high functioning, which is not clearly understood or defined. Other terms such as more able, near normal and mildly autistic have been used to describe this group of individuals whose have intellectual abilities at or above the normal range. Janzen[20] however describes the term 'high functioning' as very misleading without further qualification, because it creates an illusion that the problems are mild and little or no support will be needed. In reality, those who are higher functioning, have problems and needs similar to those who are lower functioning but at a higher level. Asperger's syndrome is presently included in the diagnostic criteria[19] as an autistic spectrum disorder and is generally considered a milder form of high functioning autism. There is some debate as to whether it should be considered a separate condition but according to Janzen,[20] more research is needed before this can be determined. Those experiencing Asperger's syndrome are generally more able in language than those experiencing autism. This complex disability does not allow learning or thinking in the same way as in normal development. It can result in a range of serious issues such as problems with language, social interaction, receiving and processing information, making sense of the world, and inappropriate behaviour.[20,21,22]

There are often two major auditory issues with those experiencing autistic spectrum disorders. These are major difficulties in comprehending verbal information and speech processing, together with overwhelming sensory stimulation.[20]

Janzen[20] described overwhelming sensory stimulation as painful and disorientating for those on the autistic spectrum. This can affect all the senses resulting in extreme sensory response to touch, certain sounds, light, smell and taste. (see 6.5.1.1. Sensory integration disorder). Autistic individuals can find a range of sounds such as crowd noise and certain types of machine generated noise painful and distressing.[23] This is difficult to scientifically qualify, as such extra sensory stimuli varies greatly from one individual to another with those on the autistic spectrum. A child affected by any type of noise in their classroom or learning space is likely to be adversely affected in their ability to learn and process information if they find their learning environment painful and distressing. Shields[22] described such sounds which may be perceived as intense to include:

- Sudden unexpected noises such as barking dogs, baby crying
- High pitched continuous noises such as mechanical fans, hand dryers, lawn mowers, vacuum cleaners etc.
- Confusing, multiple or complex sounds such as crowd noise in shopping centres school classrooms etc.

Janzen[20] and Shields[22] have quoted personal experiences of individuals experiencing autism and their responses to certain sounds. One described her ears as being like an open microphone or hearing aid on full volume and was unable to filter out irrelevant background noises. Others described the fear they had of household appliances such as food processors and vacuum cleaners, which were perceived as much louder than they actually were.

6.5.1.1 Sensory integration disorder

Kranowitz[24] defines sensory integration as the neurological process of organising information received through sensory input. Individuals on the autistic spectrum are well known to experience deficits with one or more of their senses.[25]

A lesser known group is a subset of gifted children who are also known to experience this condition.[26,27] Authors such as Mauer[28] and Ottenbacher[29] suggest that a wider group of children than originally described are affected by sensory integration disorder. Mauer describes a range of developmental disabilities, which could benefit from sensory integration therapy:[28]

- Learning disabilities
- Attention-deficit/hyperactivity disorder (ADHD)
- Pervasive developmental disabilities / disorders (PDDs), which includes autistic spectrum disorders
- Neurological impairment
- Mental retardation
- Social and behavioural problems

There have been a number of papers and increasing interest on sensory integration disorder (also referred to as sensory integrative / modulated dysfunction). This relatively new concept was developed by Ayres[30] and based on work carried out in the disciplines of neurosciences, physical development and neuromuscular function.[28,31,,32] Bogdashina[34] explained that as sensory perceptual behaviours are not included in the current diagnostic criteria, few empirical studies of sensory difficulties in young autistic children have been conducted. Furthermore, Bogdashina suggests that understanding of this complex condition has been hindered by an oversimplification of sensory problems in autism with some researchers reducing these to hypersensitivities. She suggested that it isn’t as simple as identifying the hypersensitivities of each individual, and then either desensitising or modifying the environment to solve all their problems. She concluded that hypersensitivities may merely be the consequences of other sensory perceptual differences, which may include:[34]

- The inability to filter sensory information (Gestalt perception)
- Mono-processing, - the use of one sensory channel at a time to limit the amount of information and avoid distortions

- Fragmented perception - the processing of fragments or bits of information rather than the whole picture when there is too much information to be processed
- Peripheral perception - a strategy to avoid overload by attending to items indirectly. (e.g. looking at items out of the corner of the eye or focusing on one part of an item such as the wheels of a toy)
- Delayed processing (a consequence of fragmented perception)
- System shut down of some or all of their sensory channels due to sensory overload

Ayres[31] described the visual and auditory processes to be the end products of many fundamental aspects of brain function. Mauer,[28] described a common symptom of children experiencing this condition is the inability to maintain an inadequate or appropriate state of alertness through common activities, such as focusing on and attending to tasks. This is especially the case with vast amount of auditory information that must be processed such as language comprehension.[33] Bogdashina[34] cites a number of autistic authors, such as Grandin, who consider autism as a condition largely related to sensory processing. A large number of autistic individuals have deficits in one or more of their senses. One of the most common difficulties they experience, especially in sound, is ‘Gestalt perception,’ which has been described by Bogdashina[34] as a difficulty to distinguish between foreground and background information. In the case of auditory processing difficulties, an autistic individual will have difficulties in distinguishing or filtering out the teacher's voice (the signal) from the background noise. Gestalt perception also leads to rigidity of thinking and inability to generalise concepts. Autistic individuals, especially children, are often characterised by routines and rituals, which bring comfort and as sense of security to their daily lives.[34] Tomchek and Gies,[35] cited in Mauer,[28] suggest that the inability of children on the autistic spectrum to process and integrate sensory information received, is related to the language and behavioural manifestation experienced. It is therefore not difficult to see that apart from the distress that some noises cause these children, the detrimental effect of excessive noise in causing auditory overload and augmenting the problems they already have with the receiving of information and learning. Combine the problems of auditory overload with other sensory over stimulation of the other senses, it is evident that this condition is a major obstacle to learning in a mainstream environment. Special provisions for these children in terms of targeted assistance and an appropriate physical learning environment are paramount. Techniques developed as part of sensory integration therapy such as the prescription of a sensory diet are widely used in education settings. This will include appropriate interventions and activities when a child experiences sensory overload.

However, caution was raised by Mauer[28] in extending the principle of sensory integration theory to explain deficits associated with conditions such as Down syndrome. This is because deficits associated with this condition are more likely due to abnormalities in the brain, rather than a problem of sensory processing.

Mauer[28] explains that the existing research evidence for sensory integration intervention is still controversial with criticism levelled at many studies for aspects such as small sample size, inconsistent definition of dependant and independent variables, and inconsistent outcomes. Griffer[36] conducted a critical review of the evidence and notes that reputable bodies such as the American Occupational Therapy Association have on existing evidence, supported the application of sensory integration, invention and therapies for children with learning disabilities, pervasive developmental disabilities (autistic spectrum disorder), and psychosocial dysfunction.[37] Griffer expressed a desire for collaborative work to be done by others to further investigate the effects of sensory integration intervention and therapy among children.[36]

It must be of concern that many more groups of children could be affected with varying degrees of sensory integration disorder than first thought. All may not, however, be affected in the same way and not all will be affected by abnormal auditory processing. However, there may be many children with this condition struggling in educational settings, without recognition of the difficulties they have. It is clear that much more work needs to be done to establish the extent of sensory integration disorder among children throughout the education system and to implement appropriate strategies to help them.

6.5.2 Difficulties in language and communication processing with those experiencing autistic spectrum disorders

Language and communication difficulties are well known in those experiencing autism. Janzen[20] described this characteristic as not being able to process auditory information efficiently or reliably. This means that while their hearing can be very good, the deficit lies in the processing of the auditory information transmitted to the brain. It can be very perplexing for a parent or caregiver to have a child with excellent hearing who can show extraordinary ability in music. This can include a true musical ear (i.e. singing in tune, playing a musical instrument by ear at a level well beyond normal development), but yet have the most fundamental difficulties with language. Excellent hearing does not preclude other auditory processing difficulties.[38] The lack of normal development in language and communication is usually the first apparent sign of the disability and can be detected in toddlers as young as 2 years old.

These individuals are unable to communicate and respond to human interactions and situations in a normal way. They are often unable to understand the nuance of statements such as "*Pull your socks up,*" or "*How many times have I told you……?*" Even the most capable and verbal children with autistic spectrum disorders are concrete and literal in their understanding and use of language.[20] In the above cases, an autistic person will literally pull their socks up and give the number of times they have been told without understanding the underlining meaning.

The auditory channel is still the most common means of communication and imparting of knowledge. Autistic individuals often have exceptionally good visual skills, which in many cases is far superior to their auditory skills[39]. They can remember visual images in surprising detail, and it is based upon this strength, that many new frameworks for initiatives in communication are based.

Hodgson[39] describes in detail as to why this is thought to be the case. Those experiencing autism experience difficulty smoothly and accurately controlling the shifting and re-establishing of attention, which current research suggests is due to cerebellar deficits. The early acquisition of social skills and communication skills requires an ability to rapidly select, prioritise and process of information. Their central nervous system cannot perform this complex function adequately.[39]

Hodgson[39] also describes the difficulty in attending to foreground sounds and disregarding or blocking out background noise. It is well known that in typical environments many simultaneous sound sources exist (doors banging, chatter, traffic etc) and intentional communication has to compete with such noises. A normal listener is able to focus attention selectively on the information, which is important, such as communication from the teacher for example, and selectively block out background noise to a considerable extent.[39] This is a particularly important skill in education and one which creates severe disadvantages for autistic children in receiving and processing information from the teacher. This selective processing of auditory information is a learned process and not fully developed until adulthood.[40] However some listeners are unable to carry out such selective processing and receive all auditory information with equal intensity.[39] Communication modes such as speech, hand signals and gestures are transient as they remain only for a short time. Individuals with autism and other forms of communication disorders have major difficulties in carrying out tasks that require sequential processing of transient information.[39] As an example, the giving of several discreet commands at once such as, "Eat your breakfast, then wash your face, collect your bag and wait in the car."

It is not difficult to appreciate the implications for a student with autistic spectrum disorder who experiences such difficulties to try and make sense of a transient message in a noisy environment. Often the spoken message will have passed by before the student can focus enough to receive it.[39]

A key development in the communication framework is the use of visual communication messages which give a child the opportunity to engage his/her attention before the message disappears. Such stability permits enough time for adequate processing, as these individuals appear to understand much better what they see than what they hear. A student can return to a visual message to refocus as needed.[39] Extensive work has already been conducted on such visual tools and strategies.

Shields[22] advocates the PECs (picture exchange system) as a means of initiating a request and expressing their needs. A child wanting something is trained to take a picture of what they want and give it to a person such as a parent to action. During this process language is reduced to the absolute essential.

Taking the case of command to be actioned in sequence, visual schedules are prepared showing the child what has to be done in stepwise fashion. These techniques originally developed for autism have also been found to be very useful for a range of children with auditory deficits and communication problems such as hearing impairment. They are likely to be extremely useful in classroom situations where children with hearing impairment and other auditory disorders are present.

It is now recognized that a completely different language structure and framework is needed to communicate with autistic individuals. Efforts are now being made to educate parents in these new techniques so that they can interact educate and positively contribute to the development of their children.[20,22,39] One such initiative, the Early Bird Programme,[22]developed by Shields and the National Autistic Society (UK) was introduced on trial in 2000 in New Zealand with joint funding by the Ministries of Health and Education. A small number of families with autistic preschool children were selected for an intensive programme of formal instruction, guidance and observation in working with their children. Due to the initial success of the trial programme, the government has committed funding to extend the programme to families throughout the country on an ongoing basis.

6.5.3 Auditory integration training/therapy (AIT)

Janzen[20] reports that many parents in the USA now wish procedures or treatments such as auditory integration training to be carried out on their children but it is something schools feel is outside their responsibility. The authors and practitioners of this procedure claim it will desensitise children with autistic spectrum disorders and other pervasive developmental disabilities to the sounds that they find distracting, painful, and distressing, but much controversy surrounds this procedure. It has been introduced to New Zealand and promoted among parents of autistic children.

Auditory integration training (AIT) has been widely promoted as a treatment for pervasive development disabilities including autistic spectrum disorders (ASD), attention-deficit disorders (ADD, ADHD), and individuals with auditory sensory problems. It was initiated by Berard[43] in France, and further developed by Tomatis and Bient, to assist people with auditory sensory problems[44] and has been practiced as an alternative treatment for the last decade in many countries including the USA. It has not been approved as a treatment or medical device by the United States Food and Drug Administration (USFDA)[42] or the New Zealand Ministry of Health.[41] Since that time it has become one of the most controversial topics in the field of communicative disorders and at times elicits highly charged and heated discussions between advocates and detractors of the process.[42,44]

Tharpe[42] suggests that part of the friction seems to lie in the weak basis of AIT’s theoretical framework and the targeting of children whose parents are considered vulnerable. This is probably due to the limited help that established mainstream medicine can provide.

The theoretical basis of auditory integration is not well understood and some of the suggested theories are well outside the current knowledge and understanding of the audiological processes and function.[44] Berard, the founder of the procedure, claimed in his book ‘Hearing Equals Behavior’,[43] that auditory processing problems can lead to different distortions in the auditory system (shown in peaks and valleys) that arise when people perceive sounds in an atypical manner and this could result in problems in behaviour and cognition.[43,44] Berard considered threshold differences in hearing of 5-10 dB to be significant. However this is contradicted by current knowledge of the audiological system, where variations of 5-10 dB are well within the normal range of variability.[44] Berard claimed that AIT strengthened the middle ear muscles (ossicles), which improved the ability to respond to loud sounds.[43,44] He compared his form of auditory training to physiotherapy given on an elbow stating that he made it a rule to follow to the best of his ability, this kind of purely mechanical orientation in auditory retraining. Maddell states that current knowledge of the auditory system makes this theory implausible.[44] It appears from Berard's writing, that he used very loud sounds on people he tested, as he describes in detail, patient reactions when sound intensities of the range 100-140 dB were used. There were no details given as to the doses that were administered during treatments but if sound exposures were excessive, there is the strong possibility of hearing loss and in such cases, there would certainly be a reduction in hearing sensitivity. The effects of temporary and permanent threshold shifts, which occur when the ear is subjected to certain sound level doses, are well known.

Typical AIT treatment consists of 18-20 listening sessions of 30-minute intervals over 10 consecutive days. A specially designed sound processor deletes low and high frequencies from music at random and this modulated music is transmitted to the patient's ear via headphones. Audiograms are taken before, at mid-point of the treatment period, and at the conclusion of the course of treatment.

Major concerns raised by several authors include the insufficient number of high quality peer reviewed published articles on this topic and the calibre of some practitioners who have little or no professional training in audition.[44] Much research and information is anecdotal as there are major problems in reporting AIT data. The ideal double blind studies are extremely difficult to report in children with autistic spectrum disorders and other pervasive developmental disabilities. Unless there is a large number of subjects, the matching of subjects remains a major obstacle. This is further compounded with the huge variety or spectrum of symptoms found in children with autistic spectrum disorders and other pervasive developmental disabilities. Due to the complexity of carrying out double blind studies, other forms of effectively evaluating AIT data will probably be needed.[44]

Tharpe[42] and Madell[44] draw attention to the placebo effect, which cannot be discounted. When significant amounts of money are paid for a service, parents, carers or clients usually have considerable expectation that it will work to justify the expense. This can introduce bias, as those making the investment perceive it to work irrespective of whether it does or not. If the practitioner or clinician, as well as the client have high expectations, an even stronger placebo effect can occur.[42,45] Studies by Yancer[46] and Zollweg[47] incorporated placebo control groups in evaluating the effectiveness of AIT with children diagnosed with auditory processing disorders and multiple handicaps. Zollweg's[47] findings indicated that AIT did not appear to give any more benefits than listening to 'unmodulated' music. Yancer[46]did not find significantly increased benefits from those receiving no form of auditory treatment.

Madell suggests some criteria which should be mandatory as part of this procedure. As current practitioners deliver music at sound pressure levels reaching 85 dB, equipment should be regularly calibrated to ensure that permanent hearing loss doesn't occur. There is no evidence that current practitioners intentionally exceed this level. The patient should be fully evaluated by a clinician who is competent in the fields of audition, speech language development and developmental psychology.[44]

Preliminary data reported by Madell indicate that this procedure may be effective for some children.[44] Janzen[20] has also reported that AIT appears to have helped individuals with autism that have highly sensitive hearing but, as yet, the efficacy of AIT appears inconclusive.[42] There have been some questions raised as to whether AIT should be considered an educational aid or tool rather than a form of treatment. If AIT is promoted solely as an educational aid rather than a medical device, it probably would not fall under the jurisdiction of the US FDA or the New Zealand Ministry of Health for approved medical devices and treatments. However if promoted solely on this basis, it could not be promoted as a device for treating or curing any condition associated with autistic spectrum disorder, attention-deficit/hyperactivity disorder or any physical or mental condition.

6.6 Central auditory processing disorder (CAPD)

Hall and Muellar[48] have defined central auditory processing disorder as a deficiency in transmitting auditory impulses to the higher brain centres while receptive aphasia (language deficiency) is a deficiency in the interpretation of these impulses after they have been transmitted. Assessment is carried out with a comprehensive test battery of behavioural tests with proven sensitivity to central auditory dysfunction. These include:

- Dichotic word tests
- Dichotic sentence tests
- Speech- competition test
- Auditory sequencing test

Peripheral auditory function will normally be evaluated with pure tone audiometry, word recognition, and aural immittance measures (eg tympanometry) and otoacoustic emissions for cochlear function.[48] For young children (up to age 7), the diagnosis of CAPD is difficult due to the level of speech and auditory development.[51]

Hall and Muellar list the key auditory components of auditory processing as:[48]

- **Auditory discrimination**: the ability to distinguish similarities and differences in sounds
- **Auditory memory**: The ability to retain information via the auditory channel
- **Auditory perception**: The ability to receive, process and understand sounds
- **Auditory vocal association**: the ability to draw relationships over what is heard
- **Auditory synthesis**: The ability to combine smoothly all the sounds or syllables of words to make them whole or to analyse a word into its separate sounds
- **Auditory vocal automacity**: The ability to predict future linguistic events from past experience
- **Auditory figure-ground**: The ability to distinguish and process important information by bringing it to the focus of attention while relegating other unimportant sounds to the background

The ASHA[*] Task Force (convened to define and develop coherent statements on the understanding of this condition), describe a CAPD as an observed deficiency in one or more of a group of mechanisms and processes related to auditory behaviours[49] Keith[50] states that individuals with a CAPD have difficulties with all types of acoustic distortions of auditory information including reverberation, background noise, rapid speech and competing speech. Any speech signal such as speech presented in less than optimal conditions is difficult for these individuals to understand. Hayes[51] states that features of conditions such as autistic spectrum disorder (ASD), central auditory processing disorder (CAPD), attention-deficit/hyperactivity disorder (ADHD) and dispraxia can overlap which make differential diagnosis a challenge with some children. The problem of understanding CAPD becomes more complex when other conditions co-exist involving language delay, learning difficulties, reading disorders etc.[50] A child presenting with ASD may also meet the criteria for CAPD. However the difficulties in social interactions and rigidities characteristic of ASD cannot be explained by the criteria of CAPD.[51]

There appears confusion with criteria for ADHD and CAPD. In the experience of Hall and Muellar[48] they stipulate that ADHD and CAPD are independent and unrelated

[*] ASHA = The American Speech Language Hearing Association

disorders. However the following characteristics can be shared between children diagnosed with either condition:

- Male to female ratio of 2:1
- Depressed academic performance
- Seems not to listen
- Easily distracted

For young children (up to age 7) the diagnosis of CAPD is difficult with the above audiological procedures.

6.7 Attention-deficit/hyperactivity disorder (ADHD)

A 19th century German physician, Heririch Hoffman, is credited with the first person to describe the condition and to prepare a case description of a child showing symptoms of the disorder.[52] It was first labelled as brain damage syndrome following an encephalitis outbreak in the USA in 1917 –1918 where a large number of children recovering from the condition showed symptoms of hyperactivity and short attention span. Later work found that all children who exhibited these symptoms did not suffer brain damage so the term was changed to minimal brain dysfunction. Various other terms followed until in 1980 when the American Psychiatric Association described the condition as attention-deficit disorder (ADD) with or without hyperactivity. In 1987, the term was again modified to attention-deficit/hyperactivity disorder (ADHD) along with a revision of the diagnostic criteria. There has been some debate and criticism over the loss of distinction between attention-deficit disorder with or without hyperactivity. In the current Diagnostic and Statistical Manual of Mental Disorders,[19] the disorder is described as attention-deficit/hyperactivity disorder. For the purposes of this work the terms attention-deficit disorder (ADD) and attention-deficit/hyperactivity disorder (ADHD) are synonymous.

Diagnosis and treatment of ADHD has proved difficult, complex and subject to much debate in New Zealand. This disorder could be described as among the most invisible of psychiatric disorders, where there is often no dysmorphic or physical appearance. The New Zealand Ministry of Health has recently produced a set of guidelines for the assessment and treatment of this disorder.[53] Diagnosis is made by reference to the 'DSM-1V Diagnostic Criteria for Attention-Deficit/Hyperactivity Disorder.'[19]

The aetiology of attention-deficit/hyperactivity disorder (ADHD) is likely to involve neurological and genetic factors with hereditary factors thought to account for most of the variance. The New Zealand Ministry of Health cites studies now receiving considerable support, which suggest an organic neurological problem involving frontal lobes and/or basal ganglia in the brain.[54] The Ministry also finds that social factors alone are now not considered an aetiological cause, but may exacerbate pre-existing symptoms and genetic vulnerability.

The symptoms of ADHD have been divided into the following 3 subgroups:

1. Predominantly inattentive type
2. Predominantly hyperactivity type
3. Combined type

Symptoms include persistent hyperactivity, impulsiveness and inattention.[53] These are characterised by difficulties in sustaining effort and persistence, organisation skills and disinhibition.[54] Inattention items include:[53]

- Failure to give close attention to details and making of careless mistakes in tasks and activities
- Difficulty in sustaining attention
- Inability to follow through on instructions and failure to complete tasks such as schoolwork, chores, duties etc
- Difficulty in organizing tasks or activities, and forgetfulness in daily activities
- Appearance of not seeming to listen when spoken to directly
- The problem of being easily distracted by extraneous stimuli (e.g. noise)

Hyperactivity items include:

- Fidgeting and squirming
- Leaving the seat when expected to be seated
- Running or climbing excessively when inappropriate
- Having difficulty in playing or engaging in leisure activities

- Talking excessively and acting as driven by a motor

Impulsiveness items include:

- Difficulty in awaiting their time (turn) for something
- Interrupting and intruding on others

The preschool years are the most difficult in the parents' life and in the management of these children, which can also include sleeping problems, toilet training problems, and delays in speech and motor skills. If these children enter schools they are at a higher risk of low cognitive and academic performance, including reading skills. Overseas research has found persistent disruptive behaviour, in children, experiencing ADHD and other such disorders, and this is a powerful predictor of poor adjustment in adolescence and adult hood.

ADHD in preschool age is a most important target for intervention where a severe and persistent condition exists. One issue, which appears clinically difficult, is the coexistence (comorbidity) of other related conditions. Comorbidity is a significant issue for children with ADHD and it is important to identify other comorbid disorders, which may be present. The New Zealand Ministry of Health[53] estimates that 54-67% of ADHD also experience oppositional defiant disorder, which manifests in a range of negativistic, hostile and such anti-social behaviours. Other comorbid disorders identified include a conduct disorder (20 – 56%), specific development disorders such as reading disability (8-39%), speech problems (12-27%) and in adolescence, substance abuse disorder at a rate 2-5 times that of the general population. Autistic spectrum disorders have also been listed as a comorbid condition of ADHD. Adolescents with comorbid oppositional defiant and conduct disorders have a higher risk of adverse outcomes.[53]

Children experiencing these disorders find it difficult to screen out unimportant information and focus on everything in the environment rather than attending to a single activity.[54] Background noise in the classroom becomes a major distraction, affecting their ability to learn and concentrate.[55]

These children often become noisier as they concentrate more intently and seem to need to self-talk or make other noise to focus on the task at hand. This can often be misinterpreted in the classroom or learning environment, when a teacher believes the child is becoming noisier because he/she is not working. Allowances are needed for such productive and involuntary noisiness.[56]

Selikowitz summarises the characteristics of children with ADHD which include:[56]

- Having greater difficulties with auditory rather than visual attention
- Having attention which quickly fades, with tedious tasks testing their attention the most
- Having performance inconsistency, which is characteristic of an immature or attention ability
- Moving from one thing to another and maybe lacking self-direction or being unable to occupy themselves. They can quickly become bored, disruptive and attention seeking
- Being easily distracted in classroom or similar learning environment
- Having difficulty in changing their level of attention during transitions from one setting to another
- Often becoming noisy when attending appropriately to a task

6.8 Down syndrome

Children with Down syndrome are well known to have specific deficits in language, which are often exacerbated by conductive hearing loss caused by middle ear infections.[12] A study reported by Bennetts and Flynn[12] reports that 33% of children with Down syndrome have a fluctuating hearing loss and 33% suffer a permanent loss. Like the children with other disabilities mentioned above, children with Down syndrome are especially disadvantaged as their specific deficits in language are further exacerbated by hearing loss.

6.9 Learning spaces

Children experiencing an auditory problem can often find speech and communication very difficult to isolate and process when set against high levels of background noise. These levels come from outside activities, teaching activities and other noise generated inside, all of which can be exacerbated by room reverberation. Strategies are needed to obtain the optimum room construction and perhaps a change in room culture and methods of teaching. In particular the effects of noisy learning spaces and activities on those experiencing disabilities including auditory function deficit, need thorough investigation. There are likely to be many undiagnosed children in the education system with 'invisible' disabilities. Their needs are less likely to be met than those of children with known disabilities receiving additional resourcing and support.

6.10 The New Zealand Disability Strategy

The New Zealand Government has developed 'The New Zealand Disability Strategy 2001,' a long-term policy document and embarked on wide ranging consultation process in the latter half of 2000. The strategy, which is based on a social model of disability,[57] recognises that people experiencing disability face significant barriers in achieving a full quality of life in areas such as attitudes, education, employment and access to services. Objective 3 of The New Zealand Disability Strategy, 2001[58] is to "Provide the best education for disabled people" by improving education so that all children, youth and adult learners will have equal opportunities to learn and develop in their local or regular education centres. As the classroom-learning environment is one of the most important factors in education, any effort to improve this is likely to be of great benefit to all children but especially those with auditory function disabilities.

6.11 Building standards

A number of countries are already in the process of formulating standards for control of and reducing noise in classrooms and learning spaces.[18] Wilson et al[15] have recommended that all new classrooms and similar learning spaces should be designed to meet the acoustical standards specified in 'AS/NZS 2107:2000'.[59] A proposal to require appropriate acoustical standards for new classrooms and learning spaces in New Zealand has been made and is now being considered as part of the current review of New Zealand Building Code. Literature to date on noise in schoolrooms, appears to focus on the effects on the general school children, their teachers and the hearing impaired. Only limited attention appears to be given to those students experiencing the other disabilities involving auditory function deficit. It is imperative that the needs of all children experiencing auditory function deficit are investigated along with all other children, so that appropriate measures can be included in legislation, policy and standards to be promulgated in future.

6.12 Summary

While the most familiar of the conditions affecting hearing and auditory function is probably hearing impairment, there are a number of children with other conditions, that affect their ability to adequately process auditory information.

Otitis media with effusion (glue ear) can be a serious condition in young children if left untreated, as the prolonged condition can cause serious damage to the middle ear and inner ear structures resulting in hearing loss. This has major consequence for this population in the development of speech, communication and being able to learn effectively in educational settings.

Children on the autistic spectrum are another group seriously affected by noise as the majority of them experience a sensory integration disorder, which is defined as a deficit in the neurological process of organizing information through sensory input. A subset of gifted children also experiences this condition. Children experiencing this condition often have extreme sensitivities to certain kinds of noise along with other sensory stimuli, which are described as painful and disorientating. In addition these children suffer a range of other auditory processing difficulties such as ‘Gelstalt perception,’ a difficulty to filter out important auditory information such as the teacher's voice against background noise. They can have the most fundamental difficulties with language which include a delayed processing of speech. They often have a literal interpretation of what they comprehend without understanding the nuances of many common phrases such as, "Pull your socks up."

A key development in the communication framework being used with these children is the use of visual communication messages such as the picture exchange system (PECs), which is now widely used, in educational settings and in the home.

Other therapies have been developed such as sensory integration therapy to response to sensory integration disorder and auditory integration training (AIT) as a treatment for those individuals with sensory auditory problems.

Sensory integration therapy has been accepted by reputable institutions such as the American Occupational Therapy Association, and is now widely used. On the other hand, auditory integration training remains controversial eliciting fierce debate between advocates and detractors of the therapy. The efficacy of this treatment remains unresolved.

Other groups of children affected by noise include those experiencing central auditory processing disorder, Down syndrome due to their deficits in language along with higher than normal levels of persistent middle ear infection and attention-deficit/hyperactivity disorder due to the major distraction that noise presents for them in a learning environment.

The New Zealand Disability Strategy 2001, has become a cornerstone of government policy, if not yet embodied into legislation. Objective 3 of the strategy advocates the provision of the best education for disabled people. This would include the recognition of children with identifiable needs and strategies put in place to facilitate their education. It should also include the provision of appropriate acoustical learning environments. It is imperative that the needs of all children with auditory problems are investigated and recognised so that appropriate measures can be included in legislation, policy and standards to be promulgated in the future.

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7 Noise survey methodology

7.1 Introduction

The following five research questions were proposed:

1 **The sound environment**

What are the typical noise levels encountered in a range of early childhood centres and by how much do they exceed the levels proposed by the World Health Organization for unoccupied classrooms?

2 **Personal exposure**

What are the likely personal sound exposure levels of the children and their teachers and how do these relate to the New Zealand and international occupational noise criteria?

3 **Observed effects on children**

How does noise affect the learning outcomes and well-being of special needs children mainstreamed in early education?

4 **The physical learning environment**

What is the general acoustical quality of early childhood centre learning spaces and do they comply with the recommended criteria for classrooms and learning spaces given in the current Australian/New Zealand Standard?

5 **Strategies to mitigate noise levels**

What strategies can be developed not only in classroom design, but also in legislation and teaching practice, to ensure that children and their teachers are not placed in a situation where there is a risk of hearing loss and where there are barriers to learning for special needs children?

The early childhood centres were selected according to the licensing categories of the legislation[1], *which* included a selection of *sessional* centres (kindergartens) and *all-day* centres. In general, children will be enrolled in kindergarten at 3-years of age and attend 2-hour sessions in the afternoon for 3 days a week. Children 4-5 years of age attend 3-hour sessions in the morning for 5 days a week. *All-day* centres principally provide childcare for working parents and those who choose full time early education. This sector caters for newborn babies right up to age 5. Centres are licensed as required by the legislation as either *all-day* centres (Part 1) or *sessional* centres (Part 2).[1] Within each part, there are separate licensing sub-categories for children under 2-years old (*all under 2*) and those 2-years old and over (*all 2 or over*). There is an additional licensed category for *mixed* ages which in effect combines the 2 age sub-categories allowing children from new-born to 5 years of age to be present in the same centre. This *mixed* age licence will only be granted where the Secretary (of Education) is satisfied that sufficient care and protection is provided for children less than 2-years old (*Regulation 37*).[1] In mixed centres there is usually a physical separation of the children under 2-years old and those 2-years old and over with separate rooms play areas etc to meet the requirements of the Secretary.

7.2 Study development and rationale

The results of the pilot study (Chapter 3) revealed the need for a comprehensive study measuring general noise levels inside learning spaces and the personal sound exposure of the children and their teachers. The following research protocol was designed:

1. Fixed sound level measurements were carried out over the full day for *all day* centres and for individual sessions in the *sessional* centres. Other areas such as playgrounds and additional spaces such as sleep areas were separately monitored if the centre provided separate sleeping rooms. (Details of these measurements are presented in section 7.5 of this chapter).

2. Following an assessment of the suitability of the new lightweight doseBadges, these device were acquired to carry out personal sound exposure of individual children as well as teaching staff. (Details of these measurements are presented in section 7.5 of this chapter).

3. To gauge information and feedback on learning spaces, the effects of noise on children and to identify the at-risk groups, a questionnaire was developed. (See 7-8 Questionnaire survey and 14.6 Appendices).

4. A building and environmental inspection was conducted by the researcher while on the premises using a checklist developed for consistency. Building construction details likely to affect acoustical quality of the learning spaces along with activities in the vicinity significantly contributing to background noise were recorded. The acoustical quality of each learning space was determined by the measurement of reverberation time (T_{60}) over the audible frequencies and comparing to the current standard for learning spaces. The building and environmental inspection/survey is presented in chapter 10.

5. The study appeared to raise issues with teaching staff over their aural health resulting in the managers of 3 large inner city childcare centres requesting hearing tests and so this was included in the study. (This is reported in Chapter 11.)

6. Finally the New Zealand Ministry of Education conducted a major revision of the New Zealand early childhood legislation over the same period of time as this work was carried out. Officials sought advice on how noise could be controlled in legislation given the current level of resources and expertise available. This resulted in a critical review of legislative frameworks, which had precedence in New Zealand legislation. A proposal was developed and submitted to the Ministry as part of the consultation process. (This is reported in Chapter 12).

7.3 Ethical requirements

As the study involved preschool children as participants and hearing testing of teachers, full ethics committee approvals were required. Details are given in 14-1 Appendices.

7.4 Selection of early childhood centres

Early childcare centres in New Zealand are licensed by the Ministry of Education, which kindly provided a list of all licensed centres in the areas where the study was planned. The study was centred in the Greater Wellington area with centres in the Auckland and Manawatu regions also included. Approximately 50 centres were selected to be included in the study subject to approval being gained from the centre managers and governing bodies. Of these, 20 *all-day* centres and 12 *sessional* centres participated. An effort was made to select a wide variety of centres including those with a range of demographics and in varying locations (i.e. inner city, suburban, rural).
Governing bodies were firstly approached and after consent was received, individual centres under their jurisdiction were approached and invited to take part. After receiving the necessary approvals, all parents of children were circulated with a notice informing them of the project. Teachers were asked to nominate suitable children to directly participate by wearing doseBadges. The teachers had the right to choose any child they wished due to their knowledge of individual children and their parents. However the following guidelines were provided:

- A mix of genders
- Varying personalities (eg the quiet v the exhuberant)
- Avoid children who may be troubled by the doseBadges
- Avoid children who may be more prone to cause damage to the doseBadges (eg those who often are wet with water play)
- Avoid children of oversensitive parents or those likely to object

Parents of these children were sent comprehensive information sheets and consent forms for signing. No objections were received from any parents of children at any centres which participated. Sample letters are included in 14-1 Appendices.

All centres were evaluated over one day with evaluations in approximately half of the centres being extended to a second and third day due to special circumstances such as a failure of equipment, the need for more information or other activities of interest.

An intensive study was conducted in one centre to ascertain the likely extent of variation in repeated fixed sound level measurements and personal sound exposures over consecutive days for four individual weeks. While this was principally carried out as part of another study, the fixed sound level measurements were included to give an insight into the variation of repeated sound pressure levels in the same centre and repeated personal exposure levels on the same individuals.

Figure 7-1 illustrates a typical learning space. Figure 7-2 shows a typical learning session during mat time.

Figure 7-1 Typical early childhood centre learning space

Figure 7-2 Typical setting in an early childhood centre during mat time.

7.5 Equipment used and data collected

Testing utilised the equipment as shown in Table 7-1. The data collected and noise descriptors used are given for each category of measurement.

Table 7-1 Table of equipment used and descriptors of data obtained

Instrument	Purpose	Noise descriptors used
Cirrus 831 integrating sound level meter	Fixed measurements (in centre of learning spaces	L_{Aeq} dB L_{peak} dB L_{Amax} dB
17 Cirrus doseBadges	Personal sound exposures of children and staff	Dose % and Pa^2 h L_{Aeq} dB L_{peak} dB L_{Amax} dB
3 Pulsar 60 integrating sound level meters	Additional fixed measurements and personal sound exposures of staff	Dose % and Pa^2 h L_{Aeq} dB L_{peak} dB L_{Amax} dB
Quest 500 integrating sound level meter	Personal sound exposure of staff	Dose % and Pa^2 h L_{Aeq} dB L_{peak} dB L_{Amax} dB
2 Quest M28 sound level meters (backup in case of failure)	Personal sound exposure of staff	Dose % and Pa^2 h L_{Aeq} dB L_{peak} dB L_{Amax} dB
Brüel and Kjær (B&K) 2232 instantaneous reading sound level meter	Spot checks for unexpected events of interest	Sound pressure levels dB (instantaneous readings from display)

where:

- L_{Aeq} dB = Time-average levels (A-frequency weighted)
- Dose % and Pa^2h = The personal sound exposure expressed as either Dose % or in pascal squared hours. 1.0 pascal squared hour = 100% dose which is equivalent to $L_{Aeq\ 8hours}$ = 85 dB
- L_{peak} dB = Peak level (unweighted or C-frequency weighted)
- L_{Amax} dB = Maximum sound pressure level (A-frequency weighted)

7.5.1 Fixed sound level measurements

Typical sound pressure levels inside the centres and in playgrounds were recorded by fixed sound level meters. The CR 831A sound level meter was used solely for the primary indoor fixed measurements. For additional fixed monitoring such as additional rooms and outdoor areas, the CR 700, Pulsar and Quest 500 meters were used. The M28 Quest meters were used as a backup in case of failure of the other equipment.

While it would have been ideal to place the microphones of sound level meter at the normal hearing interface, the possibility of tampering, unintentional damage and the obstruction to teachers and children in the free movement around the centre precluded this option. Microphones for all the sound level meters used were connected to the meters by extension cables and suspended at approximately 2-2.5 metres from the floor as close as possible to the centre of the learning space or obvious activity areas Placement often depended on the construction and nature of each centre. Where open ceiling trusses, beams or other supporting structures were present, the sound level meters were placed on these with the microphones hanging as shown in Figure 7-3. In other cases the sound level meters were placed in a canvas bag and suspended from a ceiling hook or other device. Where possible the meters were placed away from walls or other reflective surfaces. While no standards or codes of practice exist for the measurement of noise in early childhood centres, the relevant measurement requirements of the New Zealand standard for measurement of environmental sound [2], were applied where possible. The practice of placing sound levels meters on a tripod at a height of 1.2-1.5 meters above the ground/surface for measurements as required by this standard was not possible.

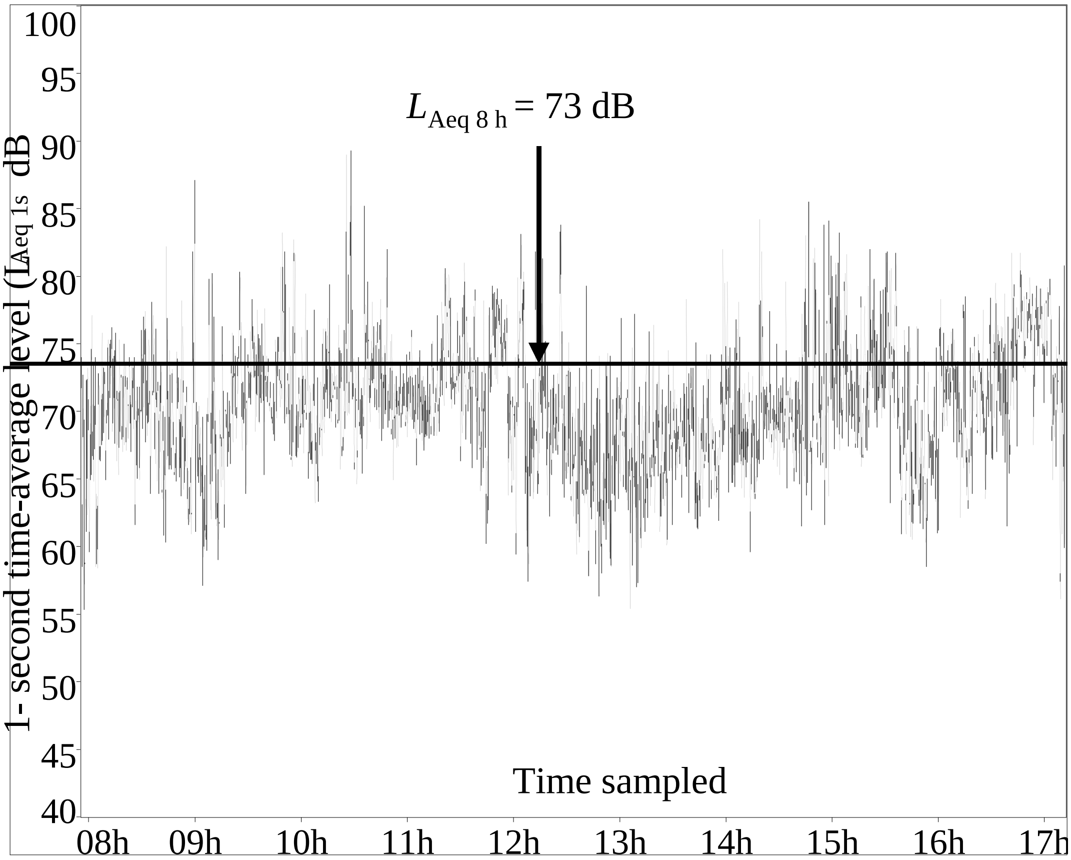
Figure 7-3 Fixed sound level meter

The following noise descriptors were recorded:

- A-frequency weighted time-average levels (L_{Aeq} dB)
- Maximum sound pressure levels ($L_{A\,Max}$)
- Peak levels (L_{peak})
- Time sampled
- Log of events was kept to ascertain as much as possible the events occurring.
- A time history was produced for each set of fixed sound level measurements. An example is given in Figure 7-4.

All meters and doseBadges were calibrated with standard tone calibrators before each measurement and checked at the end of the measurement session in accordance with manufacturer's instructions and for the standard[2] and code of practice[4] promulgated in New Zealand.

Figure 7-4 Typical time history illustration from fixed sound level measurements



7.5.2 Sound pressure levels of outdoor areas

Sound pressure levels were collected from playground and play areas where possible. Placing the meters was difficult as they had to be placed on a ledge or structure out of the reach of children. Also weather played a part as inclement weather often meant that this could not be done if shelter was not available. If placed near walls etc, the effects of reflections from these surfaces could not be discounted. Such information was still however, useful to give an indication of sound pressure levels in these areas.

Figure 7-5 A typical outdoor covered and uncovered play area.

7.5.3 Personal sound exposure of children

The difficulty of monitoring the personal sound exposures of young preschool children was overcome with the acquisition of new lightweight noise doseBadges. These instruments were developed to monitor workers in confined spaces where traditional personal sound exposure meters could not easily be used. They were small and lightweight enough to fit comfortably on children 3 years old and over. No doseBadges were fitted to children 2 years old and under due to ethics committee requirements. The doseBadges were certified as intrinsically safe and do not emit any kind of radiation such as radio waves while being worn. These units were inserted into the reader unit, the memory cleared, calibrated and activated as shown in Figure 7-6. As the children wanted the doseBadges placed where they could see them, they were pinned to clothing in the chest area as shown in Figure 7-7. Children were invited to help turn on the badges by pressing the buttons on the reader unit which seemed to overcome any initial fear or apprehension. As the doseBadges look like little spaceships there was rarely any shortage of willing participants. The manufacturer kindly supplied a number of complimentary identical looking dummy badges so that no child need feel left out. They were particularly useful in the case of child wanting a badge when the parents hadn't given consent. Despite parental consent being obtained, no child was forced or coerced to wear a badge against their will.

The children went about their daily activities with badges removed in the sleep rooms and kept near the child for the duration of their rest. Prior to the children leaving the centre, the badges were turned off, removed and data transferred into the reader unit as shown in Figure 7-6. Clearly it would have been desirable to have documented the full 24 hour exposure of the children, but this study had neither the time nor the resources to carry out such a mammoth task. Later, all the data from the reader unit was downloaded in duplicate and processed with the accompanying doseBadge software and the Cirrus Acoustic Editor programme.

The data collected from the doseBadges and personal sound exposure measurements were as follows:

- A-frequency weighted time-average levels (L_{Aeq} dB)
- Dose %
- Pascal squared hours (Pa^2h)
- Maximum sound pressure levels ($L_{A\ Max}$)
- Peak levels (L_{peak})
- Time sampled

A time history was produced for each set of personal sound level measurements. An example is given with explanations in Figure 7-8 (p.7.11). A-frequency weighted time average level lines have been added for the full sampling period (L_{Aeq} = 85dB) and for the one-hour period between the cursors ($L_{Aeq\ 1h}$ = 82dB). The doseBadge software has a capacity to produce dosimetry reports where the data from each badge use in the same sampling session can be compiled into a single report for ease of data management.

Dosimetry reports were generated for each set of measurements. An example is given in 14-5 Appendices.

The doseBadges were designed for adult use in confined spaces and for compliance with the international occupational noise criteria of:

- A-frequency weighted time-average level of no more than 85 dB for 8 hours or equivalent (100 % dose or 1.0 Pa^2h)
- A peak level of no more than 140 dB

Data collected was compared to the above criteria, which are also a legal requirement of Regulation 11 of the New Zealand *Health and Safety in Employment Regulations 1995.* Even though the above criteria do not apply for children in learning environments, data collected from the doseBadges was compared to these criteria, as no other standards were available. However it is reasonable to assume that exposure of young children to noise levels approaching the above occupational criteria is excessive.

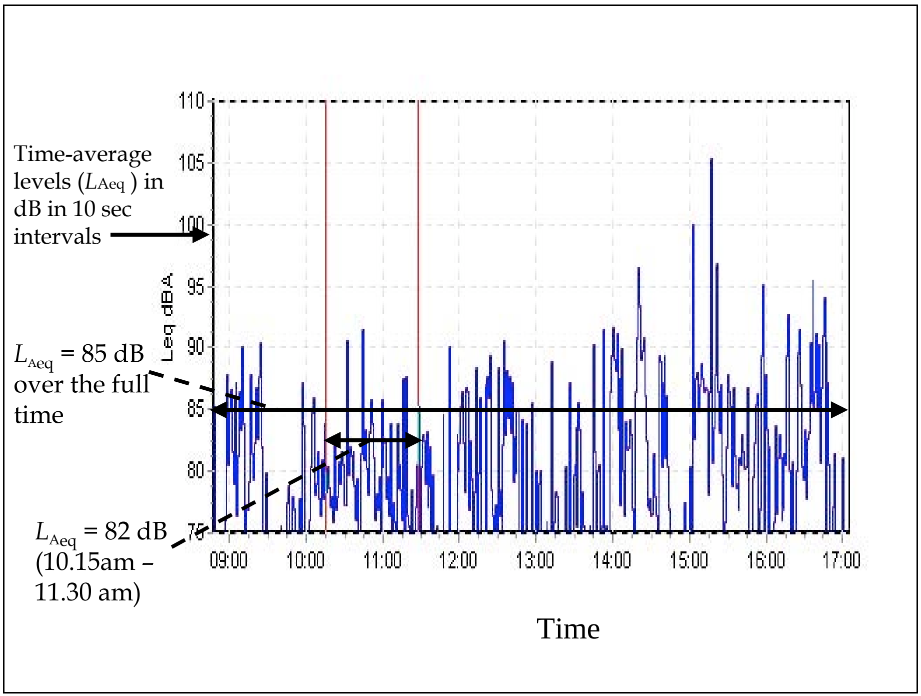
Due to memory limitations being a very small unit, the doseBadges have a high cut-off point where noise exposure data of less than 75 dB is discarded. This is not entirely suitable for children giving a conservative estimate of the children's exposure. Information on levels of noise, which will cause damage to young children, is problematic due to lack of information on this topic. The best guidance on this is given by the World Health Organization[3] where they estimate that time-average levels over an 8-hour day of 75 dB are unlikely to cause significant harm across the population. A lower cut-off point at 65 dB (i.e. data of less than 65 dB is discarded) would have given a better representation of the personal exposure of the children.

Figure 7-6 The doseBadge reader unit with a doseBadge inserted.

Figure 7-7 A child wearing a doseBadge

Reprinted with kind permission of the child and her family

Figure 7-8 Typical time-history from a doseBadge



7.5.4 *Personal sound exposure of teaching staff*

In the earlier part of the study (2003- 2004) doseBadges were principally used on children with any remaining to be used on staff. Personal sound exposure meters were also used for staff exposure where there were not enough badges. Both the doseBadges and personal sound exposure meters were calibrated and fitted in accordance with the current code of practice.[4] Personal sound exposure meters were calibrated in the same way as the fixed sound level meters with standard tone calibrators.

7.6 *Building and environmental inspection/ survey*

Using a check list, all relevant physical aspects of the building were recorded by the researcher on all centres which participated in the study. These aspects included typical construction details, internal finishes, and location to external noise generating activities. With the acquisition of an 01dB Solo sound level meter, reverberation times (T_{60}) could be easily carried out and so this parameter was introduced. Reverberation times were measured in the following frequencies 125 Hz, 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz. It wasn't possible to undertake reverberation times in all centres as this was carried out after operational hours when children were not present. Initially the sound, created by a starter gun, was digitally recorded and then manually passed through old style analogue band filters with each signal captured and processed in the Cirrus Acoustic Editor software. However this method proved faulty, as all the reverberation times calculated in many different centres were almost identical (less than 0.1 seconds apart) despite very different acoustic spaces. The fault was confirmed by conducting a test in a highly reverberant space which did not reveal the expected difference in the reverberation time. The reason for the failure of this method was not determined. All measurements by this method were discarded and as many as possible were repeated with the Solo Master sound level meter. Reverberation times were taken as close as possible to the centre of the learning space. Reverberation times were taken in different parts of the room if it was a large space with different furnishings such as carpeted and non-carpeted areas.

Measurements were taken by setting the Solo Master sound level meter to the T_{60} mode and trigger activation level of 90 dB or greater. The meter was mounted on a tripod at 1.2 – 1.5 metres in height as shown in Figure 7-8. Then a starter gun (with gun powder caps) was fired and the reverberation time was measured in duplicate. If different results were obtained a third measurement was taken.

Figure 7-9 Measurement of reverberation times (T_{60}) with Solo Master sound level meter.

7.7 Questionnaire Survey

The questionnaire was initially developed for teachers. Feedback was obtained on the acoustic characteristics in early childhood centres and the effects of noise on a range of children. While not initially intended, other groups such as special education professionals and some parents expressed interest in participation. Group Special Education of the Ministry of Education is the main provider of professional services and educational support of children with a wide range of identifiable needs through the Ongoing Resource and Renewable Scheme (ORRS). Participation from members of this group was considered invaluable as they work in many early childhood facilities where these children are placed in mainstream education. The questionnaire was modified to include this group as they do not work in any specific childhood centres and so Questions 1-7 were omitted for non-teaching specialists and parents. The modified questionnaire was otherwise identical to the full document. Teachers were invited to complete the full questionnaire while non-teaching staff such as parents and early education professionals completed the modified questionnaire. The survey along with the results obtained are described in Chapter 9.

7.8 Hearing evaluations of staff

Staff members from 2 centres specifically requested hearing tests and we decided to do this as an extension of the study. An attempt was also made to measure any temporary threshold shift in the participants' hearing as a result of the noise exposure experienced. Testing was carried out in one instance at Massey University and for the second centre at the childcare centre. Pure tone audiometry was conducted before the start of work on those staff who gave consent, and their personal sound exposure monitored with a doseBadge or personal sound exposure meter. On completion of their work, pure tone audiometry was again conducted to assess any threshold shift changes.

We were unable to conduct this in ideal conditions and did not have access to a certified hearing booth, which is preferable in audiometric testing. The sound of heavy rain occurring in one session made evaluation difficult and in another, high levels of background noise interfered with the testing procedure.

7.9 References

1 Education (Early Childhood Centres) Regulations 1998 (New Zealand Legislation.

2 New Zealand Standard, *NZS 6801:1999, Acoustics: Measurement of Environmental Sound.* 1999: Standards New Zealand.

3 World Health Organization, *WHO Guidelines for Community Noise*,. Berglund, B., Schwela, D., Editor. 1999, Occupational and Environmental Health Unit, World Health Organization: Geneva.

4 Occupational Safety and Health, *Approved code of practice for the management of noise in the workplace.* 2002, Wellington: Occupational Safety and Health, New Zealand Department of Labour.

8 Results of fixed time-average levels taken and personal sound exposures of children and staff.

8.1 Introduction

Twenty *all day* centres and twelve *sessional* centres were evaluated over one or more days.

Fixed sound pressure level measurements were taken in the main learning spaces over the full day (*all day* centres) or over the sessions held in a day (*sessional* centres). Measurements were also taken in some outdoor areas and sleep rooms. Daily sound exposures of children were measured by fitting doseBadges to individual children. Occupational noise exposure of staff was also measured with doseBadges or personal sound exposure meters. Special noise generated events such as music sessions and walking excursions were also monitored through the participants who were wearing doseBadges or personal sound exposure meters. External noise from activities such as major construction work in the vicinity was monitored where possible. Unexpected or unplanned events, such as children riding noisy tricycles, were monitored with an instantaneous reading sound level meter to estimate the sound pressure levels. Much of the noise observed was generated inside the centres by the children and their activities which included talking, shouting, crying, banging of wooden blocks or other implements or noisy exuberant activities such as table soccer, rough and tumble play etc. When children were not present, the prominent noise observed included the background of the city, traffic when near busy roads, weather if raining or strong wind and pets such as squawking caged birds or fish tank pumps.

The daily sound exposures for teachers and children have been summarised and listed in their categories of *sessional* centres and *all day* centres.

8.2 Sessional Centres

8.2.1 Children's exposure to noise

A total of 130 children were evaluated by fitting doseBadges to individual children. The daily sound exposures (DSEs) measured were:

- 82 (63.0%) received DSEs of less than 50%
- 24 children (18.5%) received DSEs between 50-100%
- 24 children (18.5%) received DSEs greater than 100%

(100% is the maximum permitted DSE for an adult worker and young children are likely to be more susceptible to the adverse affects of noise than adults).

An evaluation of the A-frequency weighted time-average levels taken over 2-3 hour sessions ($L_{\mathrm{Aeq\ 2\text{-}3\ h}}$) measured by the doseBadges on children was carried out. Of the 130 children:

- 18 children (14.0%) recorded time-average levels ($L_{\mathrm{Aeq\ 2\text{-}3\ h}}$) of less than 75 dB
- 51 children (39.0%) recorded time-average levels ($L_{\mathrm{Aeq\ 2\text{-}3\ h}}$) between 75-85 dB
- 37 children (28.5%) recorded time-average levels ($L_{\mathrm{Aeq\ 2\text{-}3\ h}}$) between 85-90 dB
- 24 children (18.5%) recorded time-average levels ($L_{\mathrm{Aeq\ 2\text{-}3\ h}}$) greater than 90 dB

Peak levels (L_{peak})

- 110 children recorded at least one exceedance over 140 dB[*]

8.2.2 Staff exposure to noise

A total of 28 staff were evaluated by fitting doseBadges or personal sound exposure meters to individuals staff members. The daily sound exposures (DSEs) measured were:

[*] Due to the limitations of the doseBadges, further information on the numbers of exceedances, when they occurred or to the actual peak levels obtained could not be determined. However, from experience, exceedances are likely to have occurred several times or more in one session.

- 23 staff members (82.0%) received DSEs less than 50%
- 4 staff members (14.0%) received DSEs between 50-100%
- 1 staff member received a DSE greater than 100%

Peak levels (L_{peak})

- 11 staff members recorded peak sound levels in excess of 140dB*.

8.3 All day centres

8.3.1 Children's exposure to noise

A total of 61 children were evaluated by fitting doseBadges for the time they were present in the centre. The daily sound exposures (DSEs) were measured:

- 19 children (31.0%) received a DSEs of less than 50%
- 16 children (26.0)received DSEs between 50-100%
- 26 children (43.0%) received DSEs greater than 100%
  (100% is the maximum permitted DSE for an adult worker)

Peak levels (L_{peak})

- 55 children recorded at least one exceedance over 140 dB[*]

An evaluation of the time-average sound pressure levels taken over 6-9 hour periods ($L_{Aeq\ 6\text{-}9\ h}$) measured by the doseBadges on children was carried out. Of the 61 children:

- 2 children (3.0%) recorded time-average levels of less than 75 dB
- 27 children (44.0%) recorded time-average levels between 75-85 dB
- 24 children (39.0%) recorded time-average levels between 85-90 dB
- 8 children (15.0%) recorded time-average levels greater than 90 dB

[*]Due to the limitations of the doseBadges, further information on the numbers of exceedances, when they occurred or to the actual peak levels obtained could not be determined. However, from experience, exceedances are likely to have occurred several times or more in one session.

8.3.2 Staff exposure to noise

A total of 45 staff were evaluated by fitting doseBadges or Personal Sound Exposure meters to individuals staff members. The daily sound exposures (DSEs) were measured:

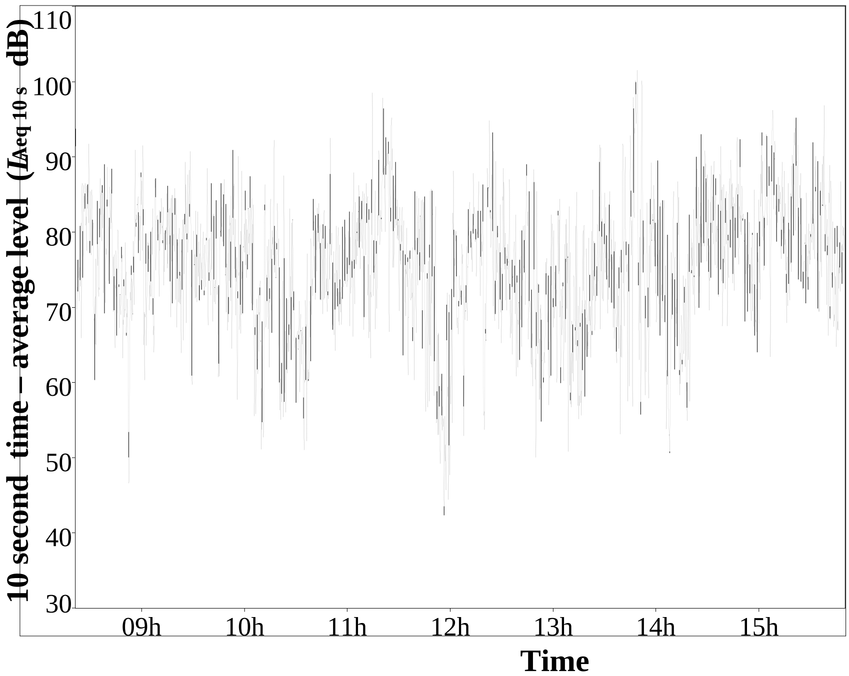
- 31 members (69.0%) received DSE s less than 50%
- 9 staff members (20.0%) received DSEs between 50-100%
- 5 staff members (11.0%) received DSEs greater than 100%

Peak levels (L_{peak})

- 19 staff members recorded at least one exceedance over 140 dB*

A typical time history from a staff member wearing a personal sound exposure meter is shown in Figure 8-1.

Figure 8-1 Time history of personal exposure to noise of a staff member. (Time given in 24 hour clock i.e. 13h = 1pm)



*Due to the limitations of the doseBadges, further information on the numbers of exceedances, when they occurred or to the actual peak levels obtained could not be determined. However, from experience, exceedances are likely to have occurred several times or more in one session.

8.3.3 Discussion of daily sound exposure results

The numbers of children and teachers monitored depended very much on the availability of the doseBadges and the ages of the children. As most teachers preferred the light-weight doseBadges to the heavier and more bulky personal sound exposure meters, efforts were made to gain a fair representation of teachers and children in each centre with the doseBadges available. Infants 2 years of age and under were not monitored as this was not permitted by the approval given by the ethics committee, so available doseBadges were used on teaching staff. When compared to *all day* centres, higher numbers of children could be monitored in *sessional* centres because two sessions are held in a single day. This enabled 2 children to be monitored with a single doseBadge. In addition, staff numbers in *sessional* centres were fewer than *all day* centres due to higher permitted staff to children ratios. In *all day* centres, individual children were monitored throughout the time they attended. This varied considerably with some children attending for a full 8-hour day. *All day* centres have higher staff-to-children ratios than *sessional* centres, so there was always a higher number of staff present in *all day* centres. This explains the reasons why there are differences in numbers of children and teachers monitored in both categories.

In the latter part of the sampling programme, the receipt of a successful research grant enabled the purchase of seven more doseBadges giving a total of 17 units. Fitting of doseBadges was time-consuming as the children, whose parents had given informed consent, had to be located, and the badges fitted under supervision. In addition, a number of dummy badges were also fitted to any other children who wanted them.

One hundred and ten of 130 children in *sessional* centres and 55 of 61 children in *all day* centres recorded peak levels (L_{peak}) exceeding 140 dB on at least one occasion. Of all the children monitored in both *sessional* and *all day* centres, this equates to 86% recording peak levels in excess of 140 dB. Unfortunately the earlier model of doseBadges was not able to give more information as to the number of exceedances, when they occurred and to what levels they reached. It would have been useful to know at what times the exceedances were occurring so as to relate back to the events occurring at these times. Sharp impact type sounds, such as dropping blocks on a wooden floor, door slamming and hammering nails can give rise to peak level exceedances. However, striking the badge against playground equipment is likely to also give false exceedances. As peak levels above 140 dB are known to cause hearing damage, it is critical that the extent of this exposure be investigated further.

In general the higher the exposure time to noise, the greater the potential risk. Therefore those children in *all day* centres, especially those who spend long hours in childcare, are at greater risk from the adverse effects of noise occurring in childcare centres. As would be expected, the DSEs are considerably higher in *all day* centres. Forty three percent of the children monitored in *all day* centres received a DSE in excess of 100% whereas 18.5% of the children monitored in sessional centres received a DSE in excess of 100%. .

It is serious cause for concern that, when considering the total number of children monitored (i.e. 191 children in both *sessional* and *all day* centres), 50 (26%) of these children received DSEs in excess of 100%, the maximum permitted for adults in the workplace. This cannot be ignored despite the limitations associated with this form of monitoring.

A thorough evaluation is needed to determine the reasons. Child participants (wearing doseBadges) who were observed to be active, exuberant, and playing vigorously, often received the highest levels as would be expected. Their own voices along with the knocking of the badges against equipment etc certainly contributed to noise and dose levels recorded. Screaming near the badge will add significant contributions to the levels l recorded. It is not generally the sound of one's own voice that will cause hearing damage, as the ear’s protective mechanisms (the muscles of the aural reflex) are activated, but the sound from other sources such as the voices of other children, especially those close by may well contribute to hearing loss. There is, however, good evidence that someone screaming and yelling will cause hearing damage to their own hearing over an extended period of time. Opera singers are at higher risk of damage from their own voices.[1]

It wasn’t possible to measure the full exposures for all the staff in *all day* centres, as many were rostered different hours from day to day. If is of concern that 5 of the 40 staff members recorded DSEs in excess of 100% and therefore in excess of the maximum noise dose permitted in the workplace.

While daily exposure rates are clearly of less concern for the *sessional* centres due to less contact time with children, it was nevertheless of concern that in one of these centres a DSE of 133% was recorded on a member of staff.

8.4 Fixed sound level measurements

8.4.1 Sessional centres

A-frequency weighted time-average levels over 2-3½ hours ($L_{\text{Aeq 2-3½ h}}$) ranged from 65-79 dB with 60% of recordings between 70-75 dB.

8.4.2 All day centres

A-frequency weighted time -average levels over 6-8½ hours ($L_{\text{Aeq 6-8½h}}$) ranged from 69-79 dB with a relatively even spread among all values.

A-frequency weighted time-average levels (fixed sound level measurements) were very similar to those reported in a review by Picard and Bradley[2] of time-average levels over eight hour day in centres with a fixed microphone, ranging from 72 dB to 80 dB ($L_{\text{Aeq 8h}}$ =72-80 dB). This similarity is surprising, as there is no standard method available as to how such recordings should be made. This is left to the judgment of those carrying out the work.

The lower figures can be explained by specific events and happenings such as school holiday times when the number of children attending was lower than usual. At one centre, when the children left the premises for a walking excursion, the time-average level over the hour period taken with a fixed sound level meter decreased sharply to 48 dB, as would be expected. This is graphically shown in Figure 8-6 (page 8.12). This time-average level ($L_{\text{Aeq 1h}}$) of 48 dB represents the background noise of the unoccupied learning space augmented with the sound generated by the few staff remaining at the centre. On the return of the children and their teachers, time-average levels rose back to the original level. The information provided by fixed sound level measurements is not representative of the daily sound exposures of the children and staff, but provides an indication of the noise level generally experienced by persons in the centres where the fixed sound level measurements were taken.

8.5 Special areas

8.5.1 Sleep rooms

Three sleep rooms in *all day* centres were monitored while children were sleeping. A-frequency weighted time-average levels (L_{Aeq}) were 60-63 dB. Personal sound exposures of teachers who spent much of their working day on sleep room duty showed very low daily sound exposure rates of 5% or less.

8.5.2 Outdoor play areas

Play areas outside were monitored where possible. This depended on weather conditions and availability of equipment. A-frequency weighted time -average levels over a full day ranged from 64 – 75 dB. The high levels were due to road/construction works occurring in the vicinity and not generated by the children. Similarly the highest level recorded was due to noise intruding from a major refitting of a different tenancy in the same building of an inner city childcare centre.

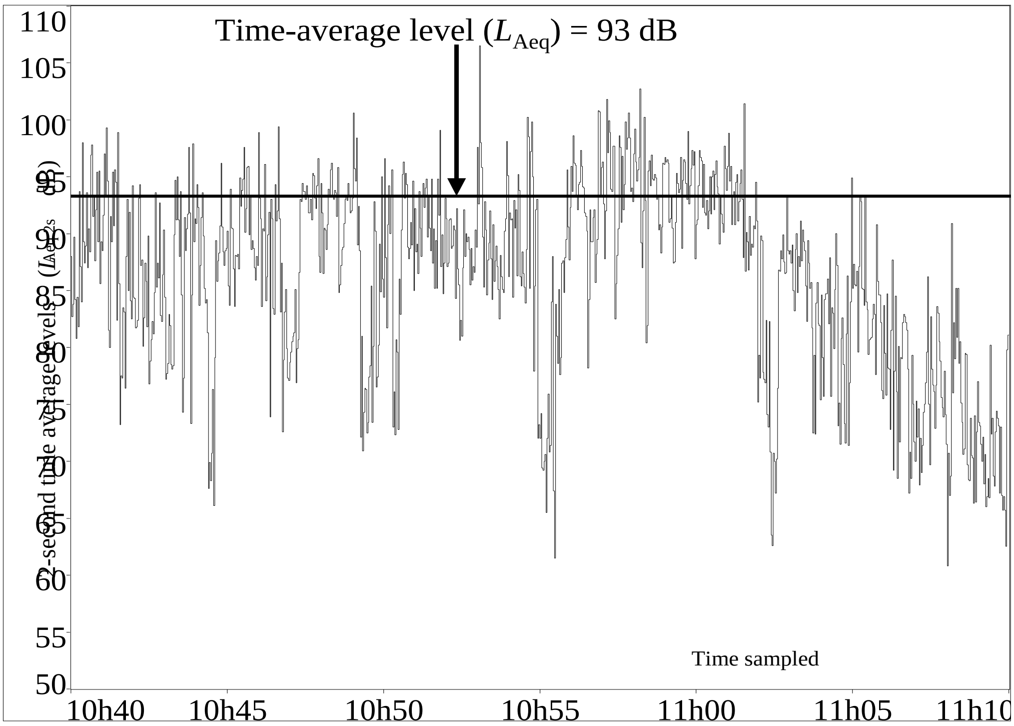
8.6 Specific events

In carrying out the recordings of noise levels, three specific events stood out as having particular significance for addressing children's exposure to noise. These events were music sessions, walking excursions, and construction works near the centre premises.

8.6.1 Music sessions

Music sessions varied greatly from unaccompanied group singing led by the teacher, singing with guitar accompaniment, and dancing, singing, and playing instruments to pre-recorded music. Musical instruments such as clackers, claves, cymbals etc., were also used. The loudest recorded music session reached an A-frequency weighted time-average level of 93 dB over the 30 minutes the session was held and approximately 25 children participated in this session. A time-history is given in Figure 8-2 below. The children experienced almost half the maximum daily noise dose allowed for an adult working in industry over a 30-minute period. The sound was produced by the volume of the stereo system, the playing of the claves, and the sound generated by the children as they participated. Expert appraisal was obtained from the Massey University Conservatorium of Music by taking an expert from the conservatorium to the centre to observe a similar music session. The expert indicated that the volume was too high and apart from potential harm to children's hearing, more musical benefit would be obtained with a lower volume. A question was raised over the sharp piecing sound of the wooden claves used by children when played in unison. The expert recommended that if claves were made of an alternative material such as plastic or flax (to reduce the sharp impact type sound), they would still give the desired musical benefit. Finally, the expert advised that music sessions could be held with smaller groups of children (even if they were shorter sessions). This would have increased benefit from not producing so much noise and perhaps allow the teacher to focus more closely on the quality of music made and musical appreciation with the children.

Figure 8-2 An excessively loud music session (note 10h40 = 10.40 am)



In another centre, the children were taught drumming and rhythm as a special activity. The children used solid drumsticks and were striking the seats of small plywood chairs, which had been raised on tables to imitate drums. The sound was loud and piercing especially when the children drummed in unison. Sound pressure levels isolated from the doseBadges on children who were drumming, showed A-frequency weighted time-average levels in the 88-90 dB for the duration of the activity. The peak levels occurring at this time were estimated to be very high, but as mentioned before, the doseBadges could only indicate an exceedance occurring, which was shown but unable to give any further information. After some discussion with staff over the level of sound, we were able to reduce the sound, without compromising the obvious benefits of the activity to the children, by placing floor cushions on the seats. It was not possible to return to the centre for further monitoring of this activity.

8.6.2 Walking Excursions

At one inner-city childcare centre we recorded the noise levels experienced by children and staff when they went on a walk. The walking excursion took just over an hour. The children and staff walked along some of the busiest streets of the Wellington Central Business District and through the city's civic square and lagoon area on the waterfront. The doseBadges recorded A-frequency weighted time-average levels (L_{Aeq}) of 82-86 dB on children and staff for the duration of the excursion. Figure 8-3 shows the doseBadge reading of a child who went on the walking excursion and Figure 8-4 expands the walking excursion section of the time history. Figure 8-5 shows the fixed time-average levels in the centre including the 1-hour period when the children and staff left the premises. During this time the time-average levels dropped to 48 dB. This finding suggests that noise levels on busy inner city streets can be very high particularly when children walk close to a heavily congested road or near major road or construction works. In a second walking excursion around major inner city road works, time-average levels (L_{Aeq}) from the doseBadges worn by children averaged 88-92 dB, while the children were walking along a temporary footpath right next to the works. While such excursions can be of benefit to children in many ways, staff should, where possible, try to avoid taking children on the busiest routes and avoid areas, which are noticeably noisy such as major construction works.

Figure 8-3 Daily Sound exposure of a child (doseBadge)

(note the walking excursion when the child left the centre)

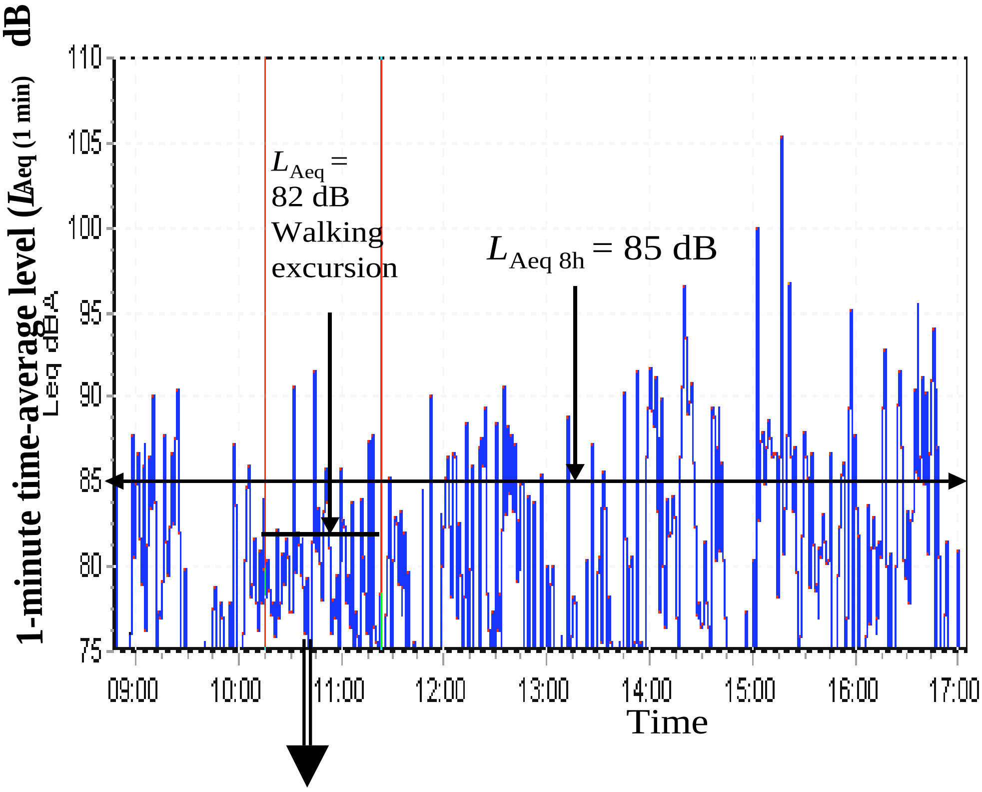


Figure 8-4 A walking excursion in the Wellington Central Business District (expanded from Figure 8-3)

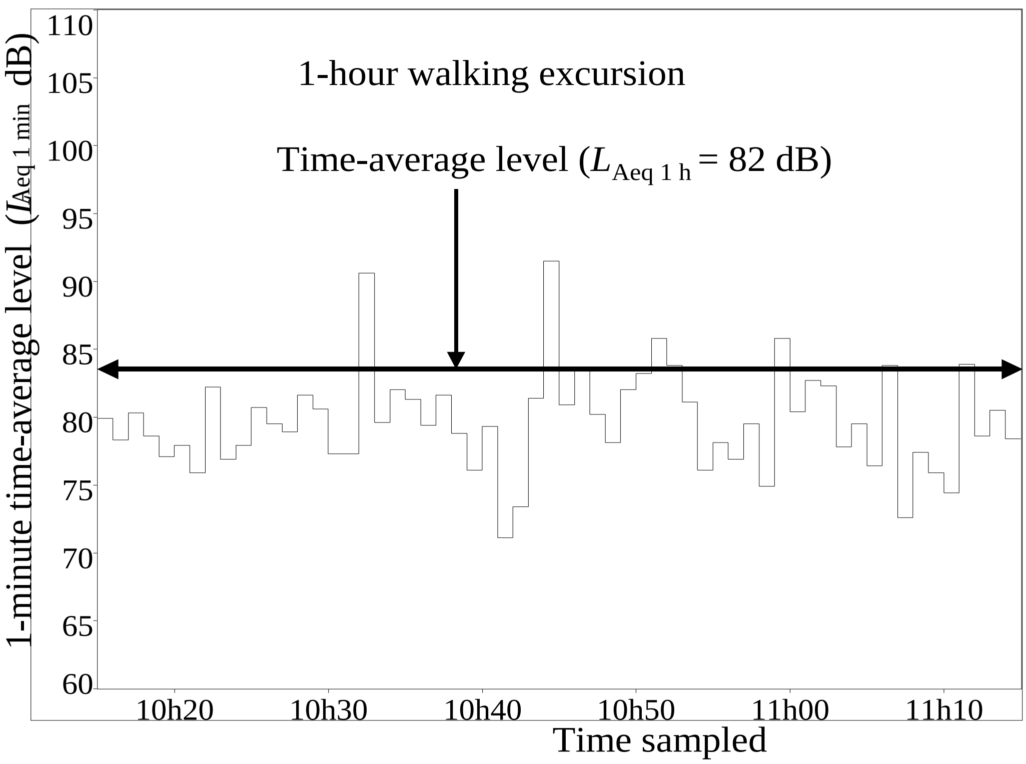
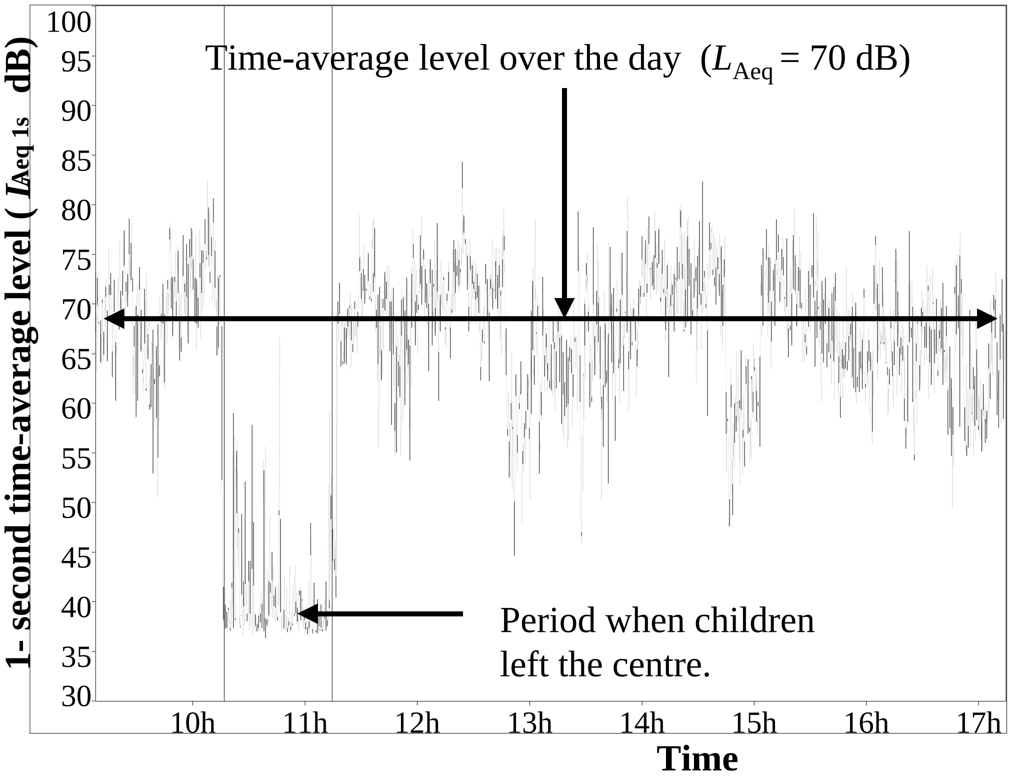


Figure 8-5 Fixed sound level measurement over a full day over an averaged eight-hour day at one inner city centre

(Time given in 24 hour clock i.e. 13h = 1pm)

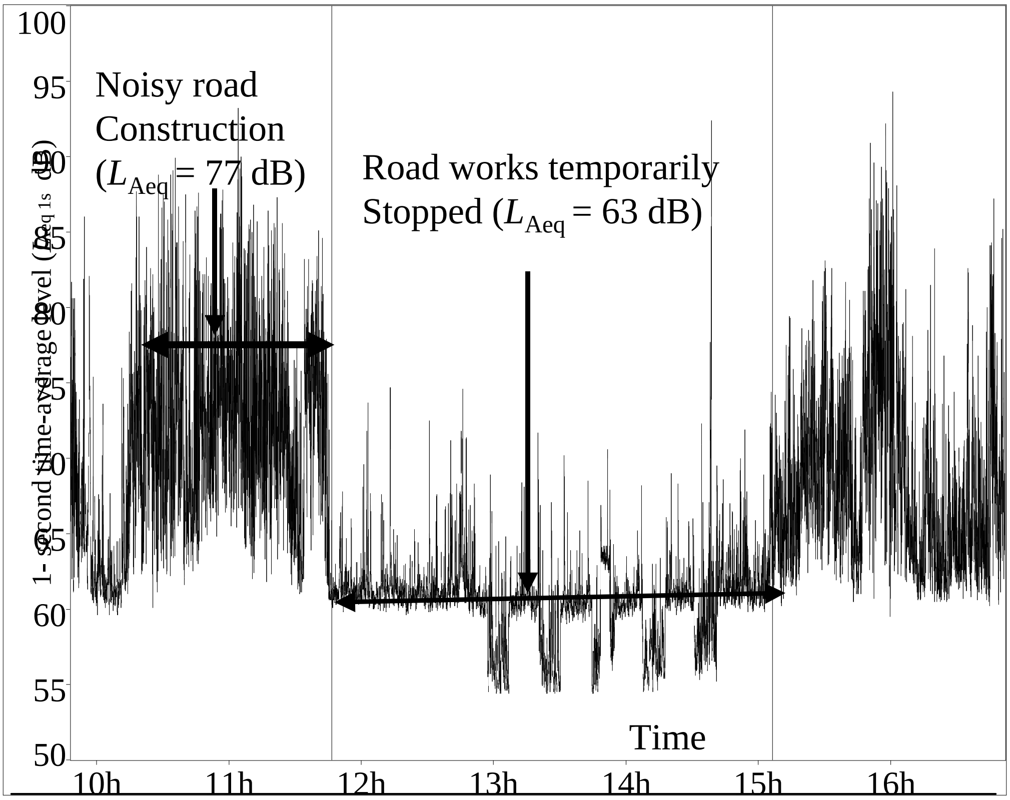


8.6.3 Construction works

Two inner-city centres and one suburban centre had major construction and drainage work occurring outside their premises. The type of noise and vibration from this activity, while intermittent, was of high nuisance value to the staff and children, and included sharp impact type sounds, squealing of machines due to lack of lubrication, engine noise and vibration during digging and pile driving. As shown in Figure 8-6 at an inner-city centre, the A-frequency weighted the time-average levels (L_{Aeq}) measured in the playground rose to between 77 dB during the times that major works were occurring outside the centre and returned to 63 dB when the works temporarily ceased. The time-average level (L_{Aeq}) over the full day was 72 dB.

A time-average level ($L_{Aeq\ 3h}$) of 75 dB was recorded over 3 hours in the play area where noisy renovations were occurring in different premises sharing the same building. In another centre, special needs children were severely distressed by the noise of sharp impact pile driving for a major road extension in the vicinity of the childcare centre.

Figure 8-6 Time history of daily sound levels taken in the playground next to major road works.



8.7 Intensive study in one childcare centre.

A study was carried out in one childcare centre for 3 hours per day, 5 days a week, over 4 weeks within a 6 month period (60 hours in total). This work was part of a project to investigate the use of music to improve the acoustic environment. Part of this work included intensive monitoring of sound levels in the centre with and without musical intervention. It provided a good opportunity to investigate the daily differences, which can occur from one day to the next and with the same children wearing doseBadges on multiple days. Fixed sound level measurements were recorded as before. Sampling occurred from 9 am to 12 noon Monday to Friday. It was not possible to sample for the full day due to time constraints and the need for sufficient time to recharge the batteries on the doseBadges.

Fifteen children wore doseBadges multiple times along with 11 teachers. One hundred and twenty six doseBadge recordings were made from the children and 47 doseBadge readings taken from the teachers over the 4-week period. There were 72 (57%) of the recordings from the children, and 20 recordings from teachers (42%), which recorded peak levels in excess of 140 dB. As both teachers and children were not monitored for the full day, it is reasonable to expect that the number of peak level exceedances would be higher if full day monitoring was carried out. Such intensive monitoring over full 8-hour consecutive days was not possible,

8.7.1 Results obtained from individual children over multiple sessions.

Results obtained by the same child on a different day were often surprisingly similar. A-frequency weighted time-average levels received by the child (1) sampled over 14 sessions varied from <75 dB-87 dB with 12 of the 14 results falling between 81-87 dB. Percent doses ranged from 7-57%, but differences here were due in part to the length of time the doseBadge was worn which varied from day to day.

The second child (recorded for 9 sessions) recorded A-frequency weighted time-average levels from < 75 dB to 86 dB except for one day where she was visibly distressed. The time-average level on this day reached 91 dB. This was probably due to crying and screaming near the badge. On the other days, this child was very placid, preferring the quieter activities such as reading, finger painting etc. The same characteristics were observed in other children, giving reasonably uniform personal exposure levels from day to day unless they were upset or distressed, which resulted in elevated personal sound exposure levels.

A very active child who engaged continuously in activities such as rough and tumble play, fighting etc., caused regular staff intervention as it was distressing other children. He generated much higher than usual levels of noise around him. His 4 results recorded over a three-hour period showed dose levels of 309%, 139%, 96% and 79%. Assuming that this child had received the equivalent level of exposure over a full 8-hour day, the equivalent daily sound exposures would have been 739%, 402%, 244% and 189%. Such levels are of great concern particularly as the dose relates to the level for an adult

A-frequency weighted time-average levels recorded over the 3-hour period with a fixed sound level meter ranged from 69-75 dB. On the first session (Monday of Week 2) major renovation work was carried out in the tenancy below. The time-average level recorded was slightly higher than recorded on most other days. However it was a noise of a high nuisance and annoyance value particularly in the outdoor play area. Observations revealed a more difficult day than usual with a number of distressed children often crying. Personal sound exposures of the children wearing the badges were examined but no major differences were observed. However, the children who were observed visibly distressed were not wearing badges. While there were a number of interlinking factors such as very cold weather confining children indoors, some children clearly feeling unwell with colds etc., the effects of the noise intruding from the outside could not be discounted as aggravating the levels of distress in some children, especially those who appeared unwell.

In the final week, the A-frequency weighted time-average levels (3-hours) recorded by a fixed sound level meter ranged from 69-72 dB and it was noticeably quieter than earlier weeks. Personal sound exposures of children were generally lower than they had recorded in earlier sessions especially on the last 3 days.

While the results and observations were not conclusive, it supports the argument that quieter environments are beneficial to the children giving a calming effect on behaviour and a positive effect on learning.

8.8 Optimal noise levels in early childhood centres

The World Health Organization recommends a background time-average level of not more than 35 dB for unoccupied learning spaces during the time they are in operation.[3] This appears an optimal guideline value for early childhood centres. The higher the levels above this value the higher the level of competing background noise with the speech and communication signal by the teachers and other children. Early childhood centres by their nature are highly interactive learning spaces where a significant contribution of all noise energy present will be generated by the children and the activities they perform. The optimal background time-average levels would ideally be no more than 65 dB averaged over 1 hour. This is based on the premise that noise levels should not be at a level to interfere with normal speech or communication nor cause any child attending distress or harm.

8.9 Summary

A significant number of children in both *sessional* centres and *all day* centres recorded daily sound exposures in excess of 100%, which is cause for concern. More work is needed as to the reasons for such high readings and to ascertain the extent of the children's own voices and play habits, which contribute to the recordings taken by the doseBadges. A higher number of staff exceeded the maximum daily sound exposure of 100% in *all day* centres, as was expected, due to the long hours on contact with the children.

A-frequency weighted time-average levels recorded by a fixed sound level meter ($L_{\text{Aeq 2-3½h}}$) varied from 65-79 dB in *sessional* centres and ($L_{\text{Aeq 6-8½h}}$) 69-79 dB in *all day* centres. These values were similar to those reported by Picard and Bradley.[2] Time-average levels dropped sharply in one centre when the children left for a walking excursion.

There were specific events where sound excessive sound levels were recorded. At one music session, the A-frequency weighted time-average level reached 93 dB in the area where the teacher and children were gathered. In another area where children were being taught drumming, sound pressure levels from a doseBadges of children participating showed A-frequency weighted time-average levels in the range of 88-90 dB. Time-average levels ranged from 82-86 dB from the doseBadge readings of children as they were taken on a walking excursion along busy streets in the central business district. In another excursion, time-average levels ranged from 88-92 dB while children were walking on a temporary footpath right next to major road works. In an inner city childcare centre with major construction works right next to the playground area, time-average levels were as high as 77 dB while the works were in operation dropping to 63 dB when the works temporarily ceased.

In an intensive study in one centre where daily sound exposures (DSEs) for individual children were recorded over multiple sessions, children who engaged in continuous rough and tumble play recorded high DSEs while others who preferred the quieter activities such as finger painting and drawing, recorded low DSEs. On days when a child wearing a doseBadge was visibly distressed the DSEs were higher than on other days.

Optimal noise levels have been proposed for early childhood centres. The WHO guideline value for unoccupied learning spaces is supported as the optimal background time-average level of unoccupied learning spaces at the times they are normally in operation. When the learning spaces are occupied an optimal time-average level is no more than 65 dB averaged over 1 hour. This is based on the premise that noise levels should not interfere with normal speech or communication nor cause any child attending distress or harm.

8.10 References

1 Sivaraj, S., *Personal Communication*, Team Leader-Audiology, Capital and Coast District Health Board, 2006.Wellington, New Zealand.

2 Picard, M., Bradley, J.,, *Revisiting speech interference in classrooms.* Audiology, 2001. **40**: p. 221-244.

3 World Health Organization, *WHO Guidelines for Community Noise*, B. Berglund, Lindvall, T., Schwela, D., Editors. 1999, Occupational and Environmental Health Unit, World Health Organization: Geneva.

9 Survey of early education staff and specialists.

9.1 Introduction

A survey of teaching staff in the centres evaluated was carried out either by interview using an open-ended questionnaire as a basis of the questions asked, or by staff completing the questionnaire in their own time. The questionnaire is given in 14.6 Appendices. Participation was completely voluntary, with participants only answering the questions they wished. The questionnaire was broadly divided into 3 parts as follows.

Part 1 was based on the model used by Wilson et al[1] on school classrooms in which information was sought from teachers about their particular teaching space.

Part 2 related the effects of noise on children suspected of being at-risk. Respondents were invited to nominate any disability they wished and with which they had experience, and to report on how noise affected these children, along with strategies used to assist them.

Part 3 gave the opportunity for respondents to identify any issues of concern, perceived health effects on teachers, existing policies within their centres and feedback on strategies already in use. The final question invited any relevant comments the respondent wished to make.

As the study became more widely known, other groups, such as professionals working with special needs children and parents, expressed interest in participation. As these groups of respondents were not directly associated with any one premises, they completed a modified questionnaire (Parts 2 and 3 only) based on their professional, clinical or parental experience. There were 15 of these reponses received, 10 were from the professional category and 5 were parent/carers.

9.2 Questionnaire - Part 1: Teaching spaces

Teachers and contact staff were asked to rate the following teaching aspects in order of importance giving each them a rating of 5 (most important) to 1 (least important):

- Lighting
- Ventilation
- Acoustics
- Equipment
- Space

Twenty responses were received for Part 1 of the questionnaire.

To gain an overall evaluation of importance among the respondents, the numerical values for each of the above aspects were grouped and summed. For ease of presentation and clarity, these values were converted to percentages of the total score. The aspect with the highest percentage score was therefore collectively rated to be highest importance and vice versa. The following overall scores were calculated.

Table 9-1 Teaching aspects

Teaching Aspect	Score rated %
Lighting	18.6
Ventilation	17.8
Acoustics	18.0
Equipment	18.6
Space	27.0

Table 8-1 indicates that aspects ‘lighting, ventilation, acoustics and equipment’ rate collectively at about the same importance. ‘Space’ was rated higher than the other aspects. On examining the results more carefully, ‘space’ was identified by the majority of respondents in *sessional* centres as most important issue affecting them. This was not the case in *all day* centres. Feedback from these respondents in *sessional* centres indicated that student-teacher ratios prescribed in the legislation were too high and the free space allocation per child insufficient. The current legislation[10] prescribes the following space standard.

Table 9-2 *Space standard* [10]

Part of premises	Area required per child
Indoor space, computed clear of all furniture fittings, fixed equipment and stored goods, and excluding passageways, toilet facilities, staff rooms, specific sleeping areas for children under 2 years of age, and other areas not available for play.	2.5 m^2
Outdoor space	5 m^2

Many respondents in early childhood centres felt that inadequate space contributed to the problems of noise to a greater extent that the acoustic parameters of the room, such as construction and finishing. Some indicated that the building acoustics were fine but having 45 children packed into a small space was the issue. The numbers of children per free space allocation was identified to be a serious issue by a number of respondents in *sessional* centres if the children could not go outside due to inclement weather. It is the policy of some governing bodies to work toward the provision of covered weatherproof outdoor areas (with clearlite roofing and blinds).

Teachers were asked to comment on the listening environment and their teaching spaces. While half of the respondents judged their listening conditions favourably, the others reported that their listening conditions were poor or very poor, citing excessive reverberation and an irritating environment as the most common negative aspects. Some respondents reported that conditions were fine if children were outside. Frustration was an aspect not listed which several respondents raised. Many found themselves shouting over the top of the children to be heard (known as the Lombard effect),[2] which has a negative impact on the children (see 4.2.1 'Effects of noise on speech and communication', p4-4). They felt uncomfortable and uneasy about having to shout to be heard and were concerned about negative effects on what is essentially shouting at the children. The transmission of foot pounding through the floor sub-frame of the rooms with outside ramps and walkways was identified as an issue in the study by Wilson et al.[1] In the few centres where there were similar external walkways sharing the same sub-frame as the floor, foot pounding was identified as a problem by respondents, especially with lightweight domestic-type floor construction.

All respondents who completed this section indicated they sometimes had problems with noise generated inside the centre. When asked what noise they found intrusive or annoying, many reported the screaming and yelling of children along with the scraping of furniture. Some identified the crashing and banging of wooden blocks, while others found the clanking of high heel shoes when children dress up to be particularly annoying. Noisy ride-on toys with hollow plastic wheels being ridden on a concrete pad were identified as very annoying in centres which had these toys. In a few centres, which had a dilapidated piano in the corner, staff found that children bashing on these to be very annoying. A number of centres have music playing as background music. The volume has been a source of tension with some staff objecting to how loud other staff members wish to play the music.

Respondents reported that they had issues with noise in their centres at some time. Of the 20 respondents, all except 2 said that most of the noise was generated by the children themselves. Of the 2 respondents, one said all the noise was generated by the children while the other said that children were responsible for only some of the noise as they were on a busy road with road works occurring.

Respondents were asked to comment on times of the day or specific events where they perceived the noise to be excessive. Many reported that noise was excessive at the start and end of sessions with the arrival and departure of the children. Parents and carers[*] have ready access to their children while at the centres and in *sessional* centres the noise that parents make was identified as a problem as children arrive and depart with their parents in the space of a short time. Some centres have sent notices home asking parents, who arrive to collect their children, to respect that the lessons are still in progress until the children are dismissed. In *all day* centres, the drop off and pick up times varied considerably so there was not the rush of parents at the beginning and end of the working day. Observations revealed that pick up and drop off times in *sessional* centres seemed quite an enjoyable and social time for parents to meet each other– hence the sound of chatter at these times which could be disturbing during lessons especially if children were sitting on the mat and listening to the teacher. Transition times when children are moved from one activity to another were reported as noisy. This may be

[*] Guardians or approved persons, other than the parents, permitted to collect and look after the child.

due to the unsettling nature of moving children into different activities. Toileting children and having them seated for a meal often generated noise until the children were settled and began eating.

Respondents were asked to estimate a percentage value for the extent of times they felt noise was excessive. Values reported ranged from less than 5% to a maximum of 50%. This suggests that noise annoyance is a problem only at specific times. Some of the higher values reported referred to an 'inside day' due to the weather. In some centres, the weather often related to attendance. In poorer areas, inclement weather often meant many children not attending due to sickness and infection. In addition those without transport, who walk their children to the centre, may keep the children at home rather than take their children to the centre in bad weather.

When asked about any environmental conditions, which have a direct affect on noise levels, all respondents identified the weather which confines children indoors. In some exposed centres, wind was identified as a major issue, both from the noise of howling gales and having to keep children inside on fine but chilly days. This centre was in a lower socio-economic area with a higher than average number of special needs children.

Respondents were asked to identify noise generated within their centre apart from that generated by children. Furniture scrape was identified by 18 of the 20 respondents as major source of noise. In some centres, which had ceiling fans to cope with summer heat, these were identified as an issue. If the ceiling fans were operating, it was a source of continual noise, which was always there and very annoying. While one centre was unoccupied, the background sound level was measured at approximately 35 dB with the fans off, rising to 50 dB with the fans switched on. The volume of the Hi Fi was identified as an issue where some staff were annoyed by the volume that other staff members wanted. The hum from fish tank pumps were identified as the sound is there all the time and can be annoying. Similar comments were made in the study by Wilson et al[1] over the similar sound of computers. Some respondents who were in centres with squawking caged birds, found these quite annoying. Other respondents had problems with squeaky play equipment due to lack of lubrication. Poorly constructed toys such as ride on tricyles, which were noisy when in use, were identified by staff as being very annoying.

In some areas, noise generated outside the control of the centres was identified as an issue with most respondents reporting that they had problems with noise generated outside their centres at times. Those who were in the vicinity of emergency vehicle stations, reported that noise of sirens could be very disruptive, particularly if there were many call outs. One respondent reported the experience in another centre of the disruption caused by the station siren for a volunteer fire service, which they felt was too loud and disturbing. The local Fire Service chief had argued it had to be of that volume to be heard in the outskirts of the District’s centre. The centres next to airports and railway lines reported issues with both of these transport activities. A centre next to a chartered club (selling liquor) had issues with the noise of bottles being stacked and barking dogs on the trucks, which frequently visited the premises. One centre, which was largely encircled by roads, had issues with boy racers around the perimeter of their centre. Another centre has issues with a motor garage with noise from engine revving, air compressor tools, horns sounding and banging. A loud school bell from the school next door was an issue for one centre. In Auckland, a respondent from the spray zone to eradicate the painted apple moth, a potentially serious agricultural pest accidentally introduced to New Zealand, reported the level of disruption caused by low flying aircraft in the eradication of this pest. One respondent reported on a centre where she had worked with major building extensions underway to extend the premises. It was, in effect, a building site behind a canvas screen and barriers, with little other provision made for the children or teachers. Many commercial gymnasiums provide childcare for children while their parents work out. Some staff has been very concerned at the level of noise to which the children and themselves are exposed. One centre was approved with a childcare centre right next to the weights room with staff concerned about the crashing and banging of weights. While it would be desirable to carry out monitoring in such facilities, the obviously sensitivities surrounding a commercial operation and perceived negative publicity, make it unlikely to obtain approval from management.

Teachers and staff were asked to comment on how noise affected them. All respondents indicated that noise affects them in some way and no respondents indicated that noise had no effects on them. Most of the respondents (about 80%) found noise to be stressful and made them feel irritable. Several complained of leaving work with a headache on days when they felt noise was excessive. The majority found noise tiring and a strain on their voices. Two respondents indicated that they experienced a tinnitus type response such as ringing the ears, which can be regarded as a warning sign of impending hearing damage. Two respondents from small special facilities such as centres or classes for special needs children, reported that noise from students was not an issue, due to the teacher-to-staff ratio of 1 teacher per 10 students. Some teachers indicated that noise was a long-term issue for them, which they encountered throughout their working lives. Half the respondents expressed concern over hearing damage as a result of their work and in the case of 4 centres, staff requested hearing tests. (The results of these hearing tests are reported in Chapter 11). Some staff members felt that what they have to do to manage noise is detrimental to their teaching practice. Some indicated that they found it difficult and tiring to try and control the environment for the benefit of children and themselves. An equal number of respondents indicated concern over voice strain and these seemed to be those with softer voices who had to strain them to be heard.

9.2.1 General effects of noise on children

Question 7 (Part 1 of the questionnaire) sought information on how noise affected children in general. The conditions listed were as follows:

- No effect
- Impairing communication between teachers and children and intercommunication with children
- Irritability
- Affects leaning ability
- Loss of concentration
- Creating behavioural problems
- Other

Not one respondent indicated that noise had no effect and all the conditions listed in the questionnaire were indicated by 18 of the respondents. Under the “Other category,” over stimulation (hypes them up) was listed by several respondents and two reported that some sensitive children felt threatened by particular sounds. A specific example was quoted by one of these respondents - a recording of "Dinosaur Rock" had caused some distress to sensitive children. Respondents felt that noise generally had a negative effect on children, their well-being and educational outcomes. Children are encouraged to use their words in negotiation rather than resort to physical means. If noise levels are such that children are unable to use their words they have been observed to resort to physical means such as grab something they want from another student or push them away to communicate their needs. In noisy situations some respondents indicated children will give up and not bother.

9.3 Questionnaire - Part 2: Noise and at-risk children

A number of special needs children are well known to be adversely affected by noise. This part of the study aimed to gain more information about these children and how typical noise and acoustic conditions affect them in early childhood settings. Information was sought from teachers, and specialists or parents. Participants were asked to nominate any conditions from the list below they wished to report on or they could nominate any other condition not included:

- Partially sighted
- Hearing loss (included middle ear infections)
- Down syndrome
- Pervasive developmental disorders
- Autistic spectrum disorder
- Asperger’s syndrome
- Attention-deficit/hyperactivity disorder
- Global developmental delay
- Other conditions resulting in delay in development, speech and communication (e.g. developmental verbal dyspraxia)
- Giftedness (added on request)

Respondents were asked to report on the effects of noise from these children and any strategies from their practice and experience, which could be used to help these children. To this end, some respondents submitted information sheets and made references to published materials to support their responses. These have been included in this work where appropriate.

A number of conditions such as giftedness and central auditory processing disorder may not usually be diagnosed until the school years and while children will experience issues in the early years of education, the condition may not be recognised until after they start school. In this case, valuable input was obtained from five parents of children who had been subsequently diagnosed with a disability of interest and were able to relate back to their preschool years.

Some respondents found it hard to make generalisations due to individual differences in children experiencing the same condition, particularly with complex conditions such as autistic spectrum disorder and developmental verbal dyspraxia. However with most conditions the respondents reported that noise adversely affects learning and communication, both with teachers and children and between the children themselves. This was particularly the case with any child having a speech or auditory impairment. Respondents indicated that some children experiencing conditions such as developmental delay, Down syndrome, autistic spectrum disorder and giftedness were often startled and distressed by loud sudden and unexpected noises such as a siren, loud machinery or sharp impact type sounds. Some noisy loud music has also caused children distress. For those children experiencing severe difficulties in speech and communication, noise only exacerbates the difficulties they already face.

There were increased complexities with those children presenting with comorbid conditions such as Down syndrome and autism for an example. However a couple of respondents pointed out that some special needs children can be quite noisy and while they may be affected by the noise around them, are quite unaware of the level of noise they generate themselves. However, sudden acute loud noises seem to act a trigger for adverse or unsettled behaviour.

9.3.1 Hearing impairment

Hearing impairment (both sensorineural and conductive hearing loss) is perhaps the most widely recognised at-risk group to noise. This is a particularly serious issue in early years due to the adverse effects of otitis media with effusion and the numbers of children affected. Respondents have reported that in addition to learning and communication impairment, high levels of noise has caused distress in some of these children. The effects of sudden loud noise on those fitted with hearing aids are well known, as these devices, unlike the auditory system, are not selective in focusing on the target sound, and amplify everything. Inclement weather with children confined indoors, presents a particularly difficult time for these children.

One observed response of the child in cases of excessive noise, is to turn off their hearing aids, which in effect isolates them and defeats the purposed of having these devices fitted. Strategies suggested included the provision of quiet times and activities which didn't generate high levels of noise. Modifications to the centres were suggested by respondents with a recommendation to increase play space with outdoor covered areas for wet and winter times. An information sheet[3] prepared as a tool for specialists and teachers was submitted by a respondent to support their responses. In the listed strategies, the following were highlighted:

- Use of the child's name to gain their attention
- Use of culturally appropriate eye contact
- Speak to the child from a distance within 2 metres
- Be aware of background noise
- If the child has not comprehended or heard, rephrase the sentence rather than repeating verbatim
- Use of other non-verbal means such as face and hand gestures to enhance communication
- Check that the child has understood by some confirmatory questions
- Use of clear voice with normal intonation. Shouting can distort the sound
- Enhance visual cues such as face to face communication and ensure that the speakers face is in the light when speaking.

9.3.2 Central auditory processing disorder (CAPD)

One condition, which is not usually diagnosed until the school years, is central auditory processing disorder. However, from reports of children with this condition, there were concerns in their earlier years of education. Because there was no specific diagnosis, the child may be denied sufficient targeted help in their early education years. A parent respondent reported that the child experienced problems with learning and noise. According to the respondents who reported on this condition, background noise can be major distraction for some of these children, along with visual distractions. The busy early childhood centre with a multitude of activities, can present a major distraction from learning and communication. Keith[4] reported that these individuals have difficulties with all kinds of acoustic distortions of auditory information including background noise, excessive reverberation, rapid speech and competing speech.

9.3.3 Attention-deficit/hyperactivity disorder (ADHD)

A respondent reported that individual case histories indicated some particular sounds can bring comfort (e.g. dishwasher) while others can cause distress (e.g. vacuum cleaner). In general, respondents reported that noise can impair learning, impair communication with the teacher and inter-child communication and cause behavioural issues with these children. High levels of noise appear to increase hyperactivity and decrease attention and concentration. The type of physical environment is quite important with some environments being far more conducive than others. A large hall with excessive reverberation and noise from the pounding of feet on a wooden floor is a more difficult environment than activities in a quiet structured preschool classroom. Having quiet times and plenty of outdoor space will benefit these children. Respondents suggested that parents could be used to select a suitable (quiet and orderly) early childhood centre for their child. Reduction of noise and movement to minimise distractions along with creating corners with reduced stimulation were suggested.

9.3.4 Down syndrome

The effects of noise vary with individual children and with those experiencing a co-morbid condition such as a combination of Down syndrome and autistic spectrum disorder as one example. In addition the prevalence of middle ear infections with this group cannot be ignored. They can be distressed by another child crying or screaming, machine noise such as a lawnmower and particularly piercing sounds such as a fire station alarm, if it is close by. Noise has been observed to cause irritability and aggravating existing behaviour and been reported as impairing learning by causing distractions from tasks and impairment of communication with other children and the teacher. When working with these children, a quiet area needs to be found in the centre. Noise reducing strategies such as carpeting and increased space such as covered outdoor areas for wet weather are highly desirable. Some respondents reported that these children can be quite noisy themselves such as banging loudly on drums and other such objects.

9.3.5 Developmental verbal dyspraxia

One respondent reported on this condition and indicated issues with learning and communication. These children need specific work on production of speech sounds and a quiet environment is essential for them to hear target sounds being spoken and for a speech therapist to hear the child's production of those sounds. Unless a quiet suitable space is available, it is extremely difficult to conduct speech language therapy with these children. If these children are placed in *sessional* centres, specialists will often not have access to a quiet suitable space for one-on-one work and will need to use the staff room or office. The respondent indicated that this is not ‘inclusive education’.[*]

9.3.6 Autistic spectrum disorder (autism and Asperger’s syndrome)

The respondents identified the most adverse outcomes with children experiencing sensory integration (modulated) disorder. Children in this group can have exceptional sensitivities to noise. As almost all of these children present with sensory integration problems, a great many of them will experience extreme sensitivities to noise.[5] Shields[6] and Janzen[7] verify the difficulties that autistic children have with noise. A wide range of noises and sounds were identified as causing distress which included:

- Sirens and whistles
- Bells and cymbals
- Unexpected sudden noises
- Machinery noise such lawnmowing
- Air hand dryers
- The din (created by many people talking i.e., crowd noise, classroom noise)
- Sharp impact explosive sounds such as pile driving or jack hammering

One respondent was critical of major construction work in the vicinity, which severely distressed and traumatised a child presenting with classical autism mainstreamed at the

[*] See 1.4 Glossary for definition

centre. This involved drop pile driving for days on end to lay foundations for a bridge motorway extension. No consultation had taken place between the council, who issued the consent, and the kindergarten.

Others reported that they suspect disruptive behaviour being used by the child so that it would be removed to a quieter and more easily managed environment. Strategies suggested were to divert tasks such as lawnmowing etc, to outside session times and if this couldn't be avoided, to thoroughly prepare the child so that they know what will happen. However, communicating or preparing young autistic children is not easy or straightforward, but allowing the child to explore something, which is noisy without a crowd around can help. Fire drills were an activity identified where preparation of these children was desirable. Visuals and pictures were used to communicate these ideas.

Respondents in general reported the main or primary adverse effects of noise with these children were:

- High levels of distress
- Aggravation of behaviour
- Putting hands over ears
- Agitation
- Self stimulating behaviours such as hand flapping or rocking
- Screaming or groaning to try and block out the sound
- Fleeing the area and refusing to go back
- Epileptic seizure in an individual case

Many respondents reported the following effects with one expert respondent labelling these as secondary effects:

- Learning impairment
- Distraction from learning and other tasks
- Compromised communication with other children and with the teacher

As children on the autistic spectrum, especially those presenting with classical autism, have serious impairments with speech production and communication, noise only exacerbates the difficulties they already have. One severe case of a child presenting with Asperger's syndrome, suffered extreme reactions to machine noise such as office equipment, photocopy machines, computer hums and even the noise created from fluorescent lights. A family respondent described the distress of this child running screaming from a public building after being exposed to such noise. At his school, he was excluded for aggressive behaviour in his first year, and it was only later that his extreme sensitivities to noise were fully recognised. The family now believe that his extreme sensitivity to noise triggered much of his inappropriate behaviour.

The most common strategies suggested by many respondents reporting on autistic spectrum disorders were to remove these children to a quiet area to escape the din (if one exists) and the provision of earmuffs or headphones playing soothing music

9.3.7 Giftedness

After a request from a group of parents and teachers representing gifted children, giftedness was included in the survey. While giftedness may be suspected in the early years, it may not be confirmed until the school years and so some parents reported retrospective experience as did those teaching young gifted children at school. A subgroup of gifted children experience sensory integration disorder as experienced by those on the autistic spectrum. Information on the types of sounds, which affected them, were similar to those identified for children on the autistic spectrum. Respondents reported noise such as bells, sirens and whistles, lawn-mowing and construction noise as very distressing for these children. Hands over ears, screaming or groaning and aggravation of behavioural issues have been similarly reported for giftedness as for autistic spectrum disorders. One respondent reported that early childhood centres were so noisy that her preschool child eventually refused to go. Another respondent told of construction works on the other side of the boundary fence to an early childhood centre in which the noise source was closer to the children than many of the construction workers. This was especially distressing for a child later diagnosed to be gifted and experiencing sensory integration disorder. This person noted that the workers were all wearing hearing protectors but nothing was provided for the children who were expected to tolerate it. In individual cases, respondents indicated from first hand experience that excessive noise was blamed for vomiting, on-going abdominal pain and an epileptic or epileptiform seizure. Noise is very distracting for these children and they are unable to concentrate in environments of high background sound levels. Information on likely numbers among gifted children is scarce. Maxwell[8] originally reported that as many as 25% could be affected based on an assessment of an internal client base of a specialist gifted centre in the USA. However this figure was later revised as the internal client base was thought to introduce bias as these individuals and their families had identified such issues and were actively seeking help. Those experiencing Giftedness would be less likely to seek help unless there was an identified need. A later estimation by Maxwell suggested 5-10%. Advice was sought from a specialist teacher at a school for gifted children as to how many children from her experience would be adversely affected by noise. She felt about 10 % of gifted children from her teaching experience would be affected and so this suggests that the later estimation by Maxwell was a reasonable prediction. However there is still considerable uncertainty which requires further investigation to establish the likely numbers affected.

It is of concern that ear muffs are often promoted as the first port of call in attending to a child overcome by noise. It is interesting here to compare the hierarchical concept of the New Zealand Health and Safety in Employment legislation[9] in managing hazards such as noise in the workplace. Clause 8 of the *Health and Safety in Employment Act 1992* proposes the elimination of noise at the source as the first line of defence. If this is not possible, then Clause 9 of the Act calls for isolation of the worker from the source of the noise. If either of the two former lines of defence cannot be reasonably carried out, only then does Clause 10 require the minimisation of the likelihood of the hazard causing harm and the provision of hearing protectors.

To give a child, overcome by noise, hearing protectors or headphones with quiet music should only be carried out as a last resort. This in effect withdraws them from their auditory surroundings and cannot be construed as inclusive education. If the noise is to a level which is distressing the child, then the first line of defence should be to reduce the sound at source. In other words, can those making the noise be effectively managed?

9.4 Issues and Strategies

Respondents were asked to comment on specific issues and problems, any low cost or effective strategies they used, to identify worthwhile suggestions for research and other ways they could be assisted. Finally they were invited to make any comment on any issue not previously covered.

9.4.1 Lack of space

Many respondents were very critical about the substandard conditions they work in and in which they expect special needs children to effectively learn. It appeared that *sessional* centres had higher numbers of special needs children. This is probably because New Zealand's Ongoing Resourcing and Renewable Scheme (ORRS) funding will not cover teacher aide hours for full time care. It is in *sessional* centres, where space and high staff to student ratio have been identified as an issue of concern. Respondents suggested that centres need to have carpeted quiet corners to allow children to escape the din as well as for one-on-one work with children who have an identified need. Difficulties would arise over the provision of separate areas as children must be effectively supervised and children cannot go behind locked doors where they cannot be visually supervised. Quiet corners are probably not sufficient if they share the same air space with a noisy area, as sound will be transmitted straight into these areas without any attenuation apart from distance. A separate room with a full height partition and closing door would be necessary to achieve any effective sound reduction. Semi-permanent office type transparent partitions could be used to create a separate quiet area/reading room which would allow effectively visual supervision on occupants and a space for children to retreat from the noise. Such as area could be used for one-on-one work with special needs children as well as other activities such as conducting interviews where some privacy was desired. A specialist respondent stated that from his/her practice all children require improved conditions for attending and listening. While the issues of those with identified needs are better recognised and understood, there are many other children who are disadvantaged by noisy environments.

The minimum standards prescribed by the New Zealand *Education (Early Childhood Centres) Regulations 1998*,[10] was the subject of frequent criticism by specialists as well as teachers. There was widespread belief that the space standard was insufficient as it didn't require or allow for the centres to create quiet spaces. One respondent suggested that it was noticeable that where centres were run as commercial enterprises, governing bodies will only meet the minimum standard and no more.

9.4.2 Excessively loud fire alarms

Excessively loud fire alarms (especially those jointly used as burglar alarms) were identified as a serious issue by many respondents. Regional Public Health (the public health authority of the Wellington region)[11] has also raised concern. Some of the sirens were reported as being so loud that children have been observed to be visibly distressed in fire drills by covering their ears with their hands, wetting their pants, and in a state of panic. Respondents raised concern that apart from the unacceptable distress that some alarms cause, having children in such a distressed state, could severely compromise a safe, speedy and orderly evacuation.

Clause 406.3 of the *New Zealand Standard (NZS 4512:2003) for Fire Detection and Alarm Systems in Buildings* requires:

- *The sound pressure level shall exceed by a minimum of 5 dB(A), the noisiest background sound pressure level averaged over a 60s period*
- *The sound pressure level of audible signals shall not be less than 65 dB (A) and not more than that 100 dB (A) measured at any normal accessible point in the room at a height of 1.8M.*

However Clause 406.5 states:

Where audible-alerting devices could cause occupants distress in areas of buildings, or where such devices would preclude proper conduct or critical emergency function, other suitable means of quickly alerting occupants shall be permissible in those areas as follows.

a) *In care or detention facilities in which there are on-duty staff available on a 24 hr basis, low level audible and/or visual devices shall be provided so as to alert all such staff where ever they may be located and whatever normal duties they may be undertaking.*

In the case of early childhood centres, Clause 406.5 is applicable as loud audible alarms have been shown to cause distress to young children and could compromise a safe and effective evacuation. On duty staff are required to be available for the full duration that early childhood centres are in operation and children are present. There is no need for on-duty staff to be available 24 hours a day for day facilities which cease to operate at night and on weekends. This clause would apply to hospitals and should apply to early childhood facilities. The present situation with excessively loud fire alarms in early childhood centres is unsatisfactory and needs urgent attention.

Regional Public Health[11] recommended that fire alarms in an early childhood centre should be no louder than 85 dB as noise above this level can cause harm and distress. If children are under 18 months of age, the alarm sound should be no louder than 75 dB, but sufficient in number to be heard in all areas.

9.5 Other pertinent comments by respondents

Many respondents supported this work and wished it to continue stating that more work needs to be done in this area. A number of respondents expressed concern about their own health and wished for more work to assess hearing loss and other related health effects among staff. Three centres specifically requested hearing tests and so the study was extended as is reported in Chapter 11.

A specialist respondent observed from his/her clinical practice that some centres are extremely skilled at teaching attending and listening skills and felt that this is something, that varied greatly from centre to centre. This included those who pay careful, attention to the design of their centres and carefully plan quiet listening times. The respondent recommended studies in this area.

A resource kit or handbook for teachers was also proposed. This would collate all existing strategies in use to manage noise. It could also be incorporated into a model noise management plan, which could then be adopted and adapted by centres to cater for their individual characteristics. This respondent praised the resourcefulness and innovation of many teachers and felt this is something to utilise to the full and celebrate.

9.6 Summary

Respondents were invited to complete an opened ended questionnaire in three parts.

9.6.1 Part 1 Individual teaching spaces

Part 1 involved the individual teaching spaces of teachers where they were asked to rate and comment on the teaching aspects of their places of work and to identify noise issues specific to their centres. Respondents were asked to rate physical parameters in order of importance. When these were collectively combined, space emerged as the item of most importance with lighting, ventilation, acoustics and equipment rated about equal. Space was identified as a serious issue in *sessional* centres along with the high staff to children ratios permitted by the legislation. While half the respondents indicated satisfaction with the acoustic environment of their teaching spaces the remainder rated their teaching spaces as very poor citing excessive reverberation along with the numbers of children and the noise they generated. All respondents had problems with noise generated inside the rooms at times. When asked for comment, many respondents in *sessional* centres, felt that the noisiest times were at the start and finish of the session and some commented on the noise which parents make. This did not seem to be an issue in *all day* centres as children arrive and leave with their parents at varying times. Transition times from one activity to another were noisy as children were settled into a new activity. Inclement weather was almost universally described as contributing to noise by keeping children indoors. When asked to comment on noise other than that generated by children, many indicated furniture scrape as something they found annoying. Those next to airports, motor garages and emergency services etc were affected by noise from these activities. When asked about the types of noise they felt most annoying, most indicated the yelling and screaming of children. Other annoying noise included the sound of hollow plastic wheels of ride-on-toys on the concrete pad. The dropping of wooden blocks along with the bashing of a dilapidated piano, were also identified as causes of annoyance.

All respondents indicated that noise affected them in some way and no respondents indicated that they suffered no effects from noise. Several respondents complained about leaving work with a headache on noisy days and many found noise tiring and a strain on their voices. Half of the respondents expressed concern over hearing damage as a result of their work. Most respondents felt that noise was of concern to the health and welfare of children and no respondents indicated that noise does not have an effect on children and a wide range of effects of noise on children were identified which included impairing communication between children and their teachers and with other children, irritability, affecting learning ability, loss of concentration, over stimulation and creating behavioural problems

9.6.2 Part 2 At-risk children

Teachers, early intervention professionals and parents contributed to this section. For those not working in a specific teaching environment, a modified questionnaire was prepared omitting the first part of the questionnaire. Respondents were asked to comment of specific disabilities known and identified in literature as being affected by noise. A wide range of disabilities were identified with hearing and auditory processing problems. Of all of these groups, children with sensory integration disorder were estimated to be the most seriously affected by noise, due to the number of adverse outcomes these children have been observed to experience. The vast majority of children on the autistic spectrum along with a subset of gifted children are known to experience this condition, which often results in extreme sensitivities to noise especially in the very young. This finding was surprising, as these groups have not been widely identified in literature on classroom acoustics, despite this being widely reported in specific clinical literature on autism and sensory integration.

Many of these children become highly distressed or even traumatised by some noise experienced in early education settings. This included excessive classroom noise, excessive reverberation, the hum and whine from machines such as air blow hand dryers, photocopiers, and noise generated outside the centre. The lack of quiet spaces in many centres was identified as one of the most pressing issues affecting the integration of children with special needs into mainstream early education. Early intervention professionals and their education support workers often have to work on a one-on-one basis with these children in their care, and often are severely hampered by the lack of suitable quiet spaces in which to work. In the case of excessive noise or auditory input, these children often have no quiet spaces into which they can retreat to escape the din.

9.6.3 Part 3 Specific issues and strategies

Respondents were asked to comment on any specific issues of concern. A range of noises such as alarms and sirens were identified as causing distress. The centres where security alarms were connected to fire alarms came in for special attention because of the excessive volume these items generate. In the case of fire drills, planning is put in place for the children known to be affected by the noise, but affected respondents raised concern about a real life situation where they will have little or no warning.

Construction noise involving loud impact type sounds intruding from activities outside one centre was found to be particularly distressing when experienced. Of concern was the apparent lack of enforcement of such activities by territorial authorities. Childcare centres should have been regarded as sensitive activities when consent was granted for major construction work in the vicinity. All such consents should have been *notified consents* under the New Zealand *Resource Management Act 1991*, and consultation with affected childcare centres should have occurred, with appropriate conditions being placed on such operations.

The following concluding statements made by 2 respondents were particularly pertinent.

- "Why do we expect children with serious auditory disabilities to negotiate their way around a noisy painful environment when we never expect a child with physical disabilities to negotiate their way up a flight of stairs?"

- "If we can get it right for our most vulnerable children, imagine how wonderful it will be for all the others!"

9.7 References

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11 Regional Public Health (Wellington, New Zealand), *Fire and Security Alarms.* Strand 1 Well Being- Manu Atua (Regional Public Health Newsletter), 2001(6): p. 3.

10 Building and environmental inspection

10.1 Introduction

The last few decades have witnessed major changes and the development of an innovative teaching practice in early education. Increased noise is perhaps a consequence of the interactive and inclusive approach, along with former design criteria, which put an emphasis on hygiene with easily cleanable surfaces. This resulted in hard reflective acoustic surfaces giving excessively long reverberation times. In addition, the conversion of typical domestic dwellings to childcare centres rather than purpose built centres, has not involved acoustical treatment as little practical information or guidelines were available.

A simple survey or inspection was carried out on each of the premises while noise levels were being monitored. There were 20 *all-day* centres and 12 *sessional* centres. It was carried out by the researcher and did not greatly involve any staff apart from seeking extra information about the presence of noisy activities in the vicinity or other aspects not immediately apparent. A building and environmental inspection sheet (see 14.6 Appendices) was developed essentially as a checklist to ensure consistency. The inspection criteria of the building was modelled on that carried out by Wilson et al[1] in their New Zealand classroom study. This would allow any comparisons between the 2 types of educational facilities (school classrooms and early childhood centres to be explored). The licence (which must be legally displayed) was first examined and the relevant details recorded (ie licensing category the number of permitted children and required staff).

The inspection was carried out using the building and environmental inspection sheet (in 14.6 Appendices) as a guide, with the aim of gathering a full profile of the physical characteristics of the centre, its operation and location. In particular, parameters known to contribute directly or indirectly to noise levels were carefully observed and recorded.

The criteria of the licence under the legislation[2] were firstly recorded, which included the number of children permitted to be enrolled and staff required (as well as current numbers of children and staff members). This was followed by a brief description of the immediate vicinity and the locality. The construction style was recorded (timber lightweight, brick-veneer etc). The presence of skylights was noted as these can be noisy when raining. Brief details of the play areas were noted and the prominent background noise when occupied determined. Careful notes of the internal construction such as ceiling type (pitched following the roof line or horizontal with an internal ceiling space), along with floor type (suspended wooden floor on sub frame or concrete pad) were recorded, as these parameters can affect the overall acoustics of the internal space. Internal linings such as wall surfaces and floor covering were likewise recorded as were the presence of any fixtures likely to influence acoustical quality. Finally, reverberation times (T_{60}) were evaluated where possible and compared to the recommendations of the current standard[3] across the audible frequencies. Reverberation times for 26 of the centres were measured and often included more than one teaching space in each centre. Because the reverberation time test involves the use of a starter gun to generate the signal (sound pressure level in excess of 90dB), this could not be done while any children were present. In addition, failure of the initial method meant that all tests had to be repeated and it was not possible to retest 6 of the 32 centres, especially if they were located outside the Greater Wellington region. Three centres had major acoustic treatment of the walls or ceiling carried out during the period of the study. The results before the application of treatment, and after treatment were recorded and have been discussed. Other centres were considering acoustic treatment at the time of evaluation. These are presented as case studies under 10.2.5.2 Examples of acoustic treatment.

10.2 Results

10.2.1 Licence details

Due to the strict conditions of the licence categories under the current legislation,[2] the numbers of the children and staff were reasonably consistent between one type of centre and another.

- A *sessional* centre is defined as a facility where children attend for no more than 4 hours per day.
- An *all day* centre is defined as a facility where children attend for a period greater than 4 hours per day.

10.2.2 Numbers of children

Regulations 8 and 37 of the legislation[2] restrict the maximum number of children to 50 in any licensing category at any one time. For children under 2, a maximum number of 25 is permitted at any one time. Other restricting factors are the amount of free floor space allocated per child and the number of available staff.

10.2.2.1 *Sessional* centres

In *sessional* centres, the numbers of children was directly related to the number of staff present. While *sessional* centres are permitted for under 2 year old children there are in reality very few and none were encountered in this study. The staff requirements for *sessional* centres are as shown in Table 10-1.[2]:

Table 10-1 Staffing requirements for *sessional* centres included in the study (Schedule 3- Part 2)[2]

Ages of children	Number of children attending	Minimum staff
All 2 and over	1-8	1
	9-30	2
	31-45	3
	45-50	4

Of all the *sessional* centres evaluated, there were a few centres with 2 staff and 30 children enrolled (or close to this maximum) whereas the majority were centres with 3 staff with 40-45 children enrolled. Few *sessional* centres had 50 enrolled, as this would require an extra staff member essentially for the 5 extra children.

10.2.2.2 *All day* centres

Many of the *all day* centres followed a similar pattern to *sessional* centres with the numbers of children present related to legislative requirements. Staff requirements are shown in Table 10-2.[2]

Table 10-2 Staffing requirements for *all day* centres included in the study (Schedule 3- Part 1)[2]

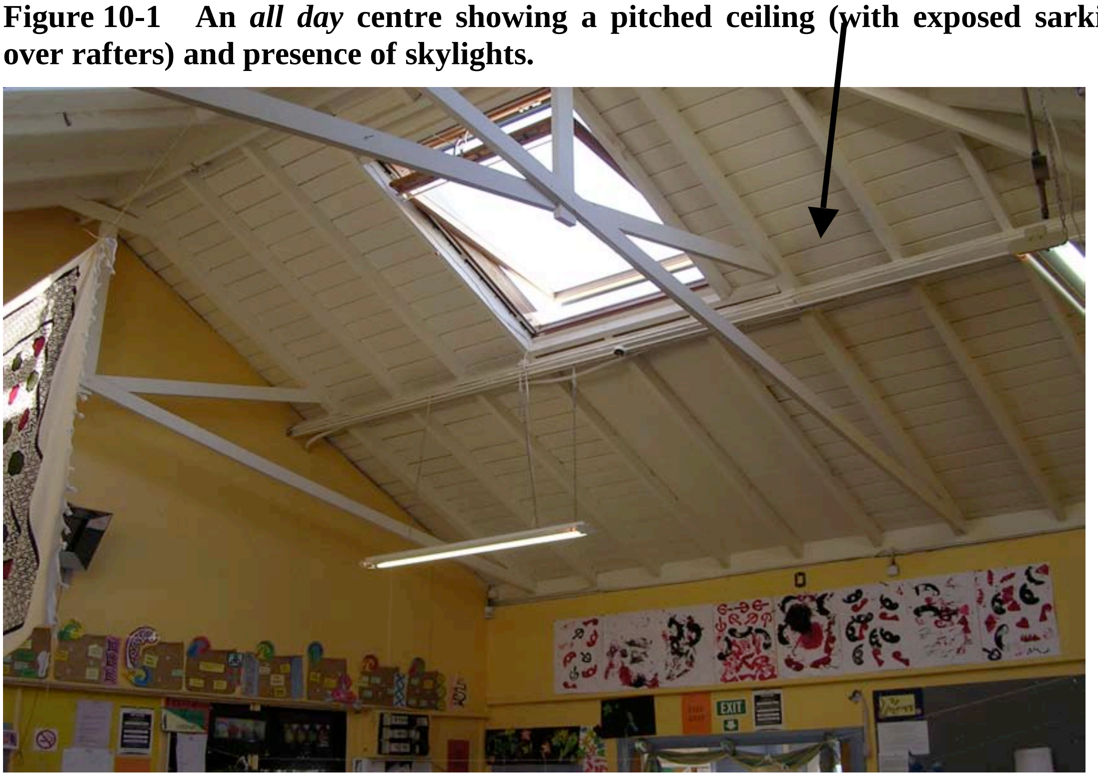
All day centres		
Ages of children	Number of children attending	Minimum staff
All under 2	1-5	1
	6-10	2
	11-15	3
	16-20	4
	21-25	5
All over 2	1-6	1
	7-20	2
	21-30	3
	31-40	4
	41-50	5
Mixed ages		
Under 2	1-5	1
	6-10	2
	11-15	3
	16-20	4
	21-25	5
2 or over	1-6	1
	7-20	2
	21-30	3
	31-40	4
	41-49	5

The majority of *all day* centres with children aged under 2 had 11 - 20 children enrolled. There were 10 of these centres having children in the under 2 age range although 6 of them were licensed as *mixed* centres having caring for new-born babies right through to school starting age. It is usual practice to physically separate both groups of children in into designated areas and this happened in all except one centre. *Mixed* category centres are required to provide adequate protection to the babies and very young children as a condition of licensing under the legislation.

10.2.3 Observations of building style

There were no distinct patterns found with the types of buildings and construction used for early childhood facilities. This is because early childhood centres were often established as stand-alone facilities in existing buildings characteristic of the locality. In the Central Business District, early childhood centres were usually located in commercial office buildings and shared with other tenancies. In residential areas, many were ex-single unit dwellings built in the domestic type timber frame construction with weatherboard cladding or brick construction with corrugated iron or tile roofing. While there were some purpose built facilities, most had been converted from a previous use. The lack of natural light and high-pitched roofs characterised several facilities. In two centres internal windows and skylights had been installed to try and increase the natural lighting. The high-pitched ceiling (with sarking over exposed rafters) followed the roof line as shown in Figure 10-1.

Figure 10-1 An *all day* centre showing a pitched ceiling (with exposed sarking over rafters) and presence of skylights.



Few centres had any noticeable acoustic treatment, except those that had embarked on projects to improve the acoustic environment with acoustic wall and / or ceiling panels. In three centres where acoustic ceiling panels had been fitted, these had been incorrectly painted over in redecorating and thus their acoustic absorption potential had been negated.

10.2.4 Localities

Localities varied widely with early childhood facilities in almost every type of community including the central business district, school and tertiary educational institute campuses, church campuses, residential areas and as an adjunct service in commercial facilities such as public swimming pools and health and fitness centres. This is not to mention the many playgroups, special education facilities, hospital based services and ethnic based centres such as kohanga reo (Maori language nests), which could not be included in this work. Levels and types of background noise observed varied widely depending on locality. Centres located in the Wellington Central Business District had fairly high background noise levels such as that generated by traffic if located next to a busy road such as a motorway. Those located well away from busy roads or other noise generating activities seemed surprisingly quiet for a central business district location. Childcare centres were also located in multi-storeyed complexes with verandas or large decks for play areas.

10.2.5 Reverberation times

Reverberation times (T_{60}) were recorded in the standard frequencies of 63, 125, 500, 1000, 2000 and 4000 Hz. Selected examples have been presented in tabular form with the times in important frequencies of 500, 1000 and 2000 Hz highlighted. For comparative purposes, some examples of reverberation times taken before and after treatment have been presented in graphical form. The standard for building interiors[3] recommends a reverberation time (T_{60}) of 0.4-0.6 seconds in classrooms and learning spaces. For young children, who are immature listeners, a reverberation time of 0.4 seconds creates the optimum acoustic conditions.

10.2.5.1 Individual assessments

Reverberation times recorded for the room shown in Figure 10-1 are given in Table 10-3.

Table 10-3 Reverberation times (T_{60}) for room shown in Figure 10-1

Frequency Hz	T_{60}
63	0.26
125	0.58
250	0.57
500	0.68
1000	0.74
2000	0.73
4000	0.66

These figures were typical of many centres evaluated, most of which recorded reverberation times of 0.6-0.8 seconds. In this case, these times could be reduced by covering the match lining ceiling surface with acoustic tiles. As an alternative, acoustic absorption panels could be suspended from the ceiling.

Of all the centres evaluated for the first time, almost all were higher than 0.4 second in the critical frequencies 500, 1000, and 2,000 Hz. One purpose built centre built 25 years ago (shown in Figure 10-2) was an exception, with the reverberation times given in Table 10-4. The ceiling was sprayed with an asbestos-containing “Gibtex” type finishing. At the time of inspection funds were being sought to remove this in accordance with modern building practice to progressively remove asbestos containing materials from all buildings. The soft textured surface would probably attenuate the level of reverberation in the learning space. If the textured surface was removed and repainted with a hard reflective surface it may increase reverberation times and therefore degrade the acoustical quality of this learning space. It was therefore important to carefully consider appropriate remediation once the texture surface was removed.

Figure 10-2 Purpose built early childhood centre. (The ceiling and upper wall to top of window sills coated with asbestos containing textured finish)**.**

Table 10-4 Reverberation times (T_{60}) for room shown in Figure 10-2

Frequency (Hz)	T_{60} (s)
63	0.23
125	0.36
250	0.49
500	0.48
1000	0.50
2000	0.45
4000	0.39

The ceiling has been coated with a asbestos-containing textured finish. As this is a soft surface, it is likely to contribute significantly to the acoustical quality of the room. The centre has sought funding to remove this textured coating and could consider replacement with acoustic tiles (rather than a plastered- painted surface) to maintain the acoustic conditions of the learning space.

Another purpose-built large childcare centre complex containing 4 teaching spaces was evaluated. The following reverberation times were recorded.

Table 10-5 Reverberation times (T_{60}) of a purpose built early childhood centre complex

Hz	T_{60} *Room 1*	T_{60} *Room 2*	T_{60} *Room 3*	T_{60} *Room 4*
63	0.11	0.19	0.18	0.21
125	0.29	0.42	0.65	0.43
250	0.67	0.85	1.02	0.81
500	1.00	0.91	0.88	0.88
1000	0.90	0.90	0.91	0.91
2000	0.82	0.86	0.83	0.78
4000	0.71	0.76	0.72	0.68

As can be seen, the reverberation times were well above the recommended values of 0.4-0.6 seconds. The building, although acoustically poor, had other good features such as plenty of natural light and a warm inviting environment. The staff from this complex who responded in the questionnaire (Chapter 9) reported their acoustic teaching environment as 'good' or 'very good' and were obviously not troubled by the high levels of reverberation. An interesting observation revealed that "space" was not a concern in this centre as it had a much higher level of space per child than many other observed. In this centre they were one of the few that had enough space for the parents to have their own lounge area away from the children. This centre had a floor area over twice that of other centres with the same number of children. A large floor area can mean that children can spread out and perhaps engage in a wide choice of activities, especially during inclement weather which confines children indoors. Another respondent in a small centre where lack of space was a pressing issue stated, "There is nothing wrong with the building acoustics or otherwise it is the overcrowding due to inadequate space." It lends argument to the fact that having a large useable space and good pleasant environment may have a significant influence on the teachers' perceptions of their teaching spaces irrespective of other physical parameters

Another early childhood corporation with 4 separate centres were evaluated. These facilities were located in former brick houses with similar design and finishes. All the centres were well decorated and well presented. Staff who responded to the questionnaire, were all satisfied with their teaching spaces. Reverberation times for these 4 early childhood centre are given in Table 10.6.

Table 10-6 Reverberation times (T_{60}) for the 4 corporate childcare centres.

Frequency (Hz)	T_{60} Centre 1 (mixed age).	T_{60} - Centre 2 Age 3-5	T_{60} -Centre 3 Age 2-3	T_{60} Centre 4 Age <2
63	0.15	0.17	0.15	0.15
125	0.47	0.47	0.42	0.67
250	0.62	0.47	0.50	0.49
500	0.59	0.55	0.60	0.43
1000	0.68	0.54	0.65	0.67
2000	0.62	0.50	0.60	0.63
40000	0.55	0.49	0.46	0.54

A centre located in a former traditional style classroom recorded the following reverberation times. This centre had a generous space allocation per child with plenty of natural light. Staff reported that they were happy with their teaching space.

Table 10-7 Reverberation times (T_{60}) of a centre located in a traditional style classroom building

Hz	T_{60} Back of room	T_{60} Front of Room
63	0.16	0.20
125	0.48	0.48
250	0.73	0.64
500	0.77	0.75
1000	0.81	0.81
2000	0.76	0.83
4000	0.69	0.77

It appears from the respondents to the questionnaire that satisfaction with the other teaching aspects can also influence the perception of acoustical quality. If a centre has a number of perceived good aspects such as adequate space for the number of children present, good natural lighting and ventilation, it seems that teachers are less likely to notice poor acoustics. Likewise dissatisfaction with other teaching aspects is likely to negatively influence perceptions of acoustical quality.

10.2.5.2 Examples of acoustic treatment

Two centres following the initial evaluation, decided to undertake professional acoustical treatment. Descriptions are given as Cases 1 and 2 below. In Case 3 the staff in the centre undertook acoustic treatment themselves. In Case 4 the governing body was seeking advice as to appropriate treatment at the time of this work.

Case 1

A *sessional* centre with a staff of 2 and an enrolment of 30 children carried out acoustical treatment of the walls. These surfaces, except for some upper areas were covered with New Zealand manufactured Autex vertiface composition acoustic wall covering. This product has a noise reduction coefficient (NCR) of 0.4.[4] This means it will typically reduce reverberated noise by 40% in the frequencies of 250, 500, 1,000 and 2,000 Hz. Figure 10-4 shows a section of wall covering. The walls were covered fully from the floor to the underside of the sill of the upper windows. The reverberation times before the treatment and after the installation are given in Table 10-8 and presented as a graph in Figure 10-3.

Table 10-8 Reverberation times (T_{60}) for Case 1

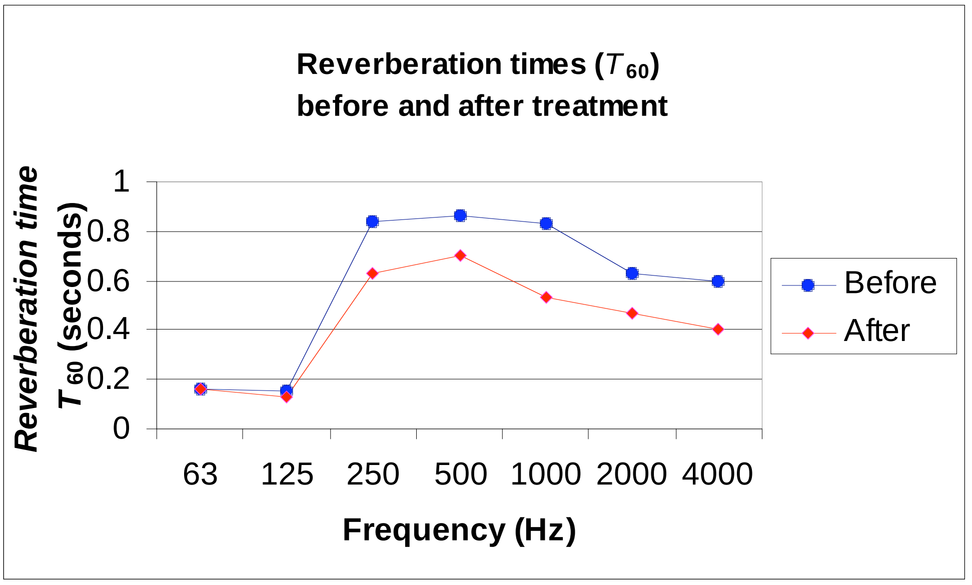
(a) Main teaching space before and after acoustic wall treatment)

Frequency Hz	T_{60} (before treatment)	T_{60} (after Autex panel installation).
63	0.16	0.16
125	0.15	0.13
250	0.84	0.63
500	0.86	0.70
1000	0.83	0.53
2000	0.63	0.47
4000	0.60	0.40

(b) Music room before and after acoustic wall treatment

Frequency (Hz)	T_{60} (before treatment)	T_{60} after Autex panel installation
63	0.30	0.16
125	0.38	0.15
250	0.69	0.59
500	0.83	0.63
1000	0.76	0.49
2000	0.59	0.37
4000	0.53	0.35

Figure 10-3 Graph of reverberation times for Table 10-8 Case 1



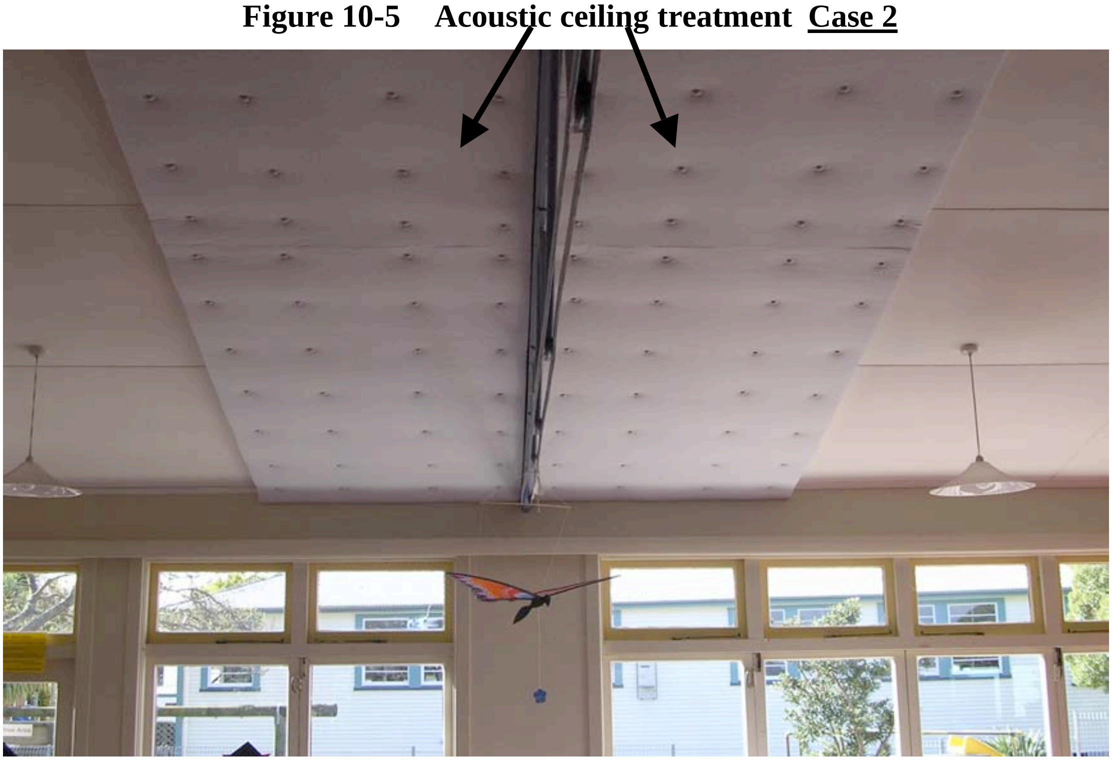
There has been a noticeable improvement in reverberation times as a result of the Autex composition wall panel application with reductions up to 0.3 seconds in the critical frequencies for both rooms. These times could be further reduced by fitting of acoustic tiles to the ceiling.

Figure 10-4 Acoustic wall treatment to the upper window sill <u>Case 1</u>

Case 2

This sessional centre had generated many complaints from staff. Management sought advice from a consultant who installed a soft absorbent ceiling material over 50% of the ceiling. The product used was Autex AAB 35/50 acoustic blanket with an NRC of 0.8. This can be seen in Figure 10-5 with the acoustic blanket firmly bolted to the existing ceiling on each side of the metal trusses. To the left and right of the soft panels, the existing ceiling surface can be seen.

Figure 10-5 Acoustic ceiling treatment Case 2



This centre recorded the highest reverberation times of any *sessional* centre before acoustic treatment was carried out, and with an enrolment of 45 children, this centre had the potential to be very noisy. High noise levels were also recorded in the monitoring of fixed and personal sound exposure levels. A staff member in this centre recorded the highest personal daily sound exposure recorded in *sessional* centres of 133%.

The reverberation times before treatment and after the installation of the acoustic ceiling panels are given in Table 10-9 and presented as a graph in Figure 10-6.

Table 10-9 Reverberation times (T_{60}) for room shown in Figure 10-5 Case 2

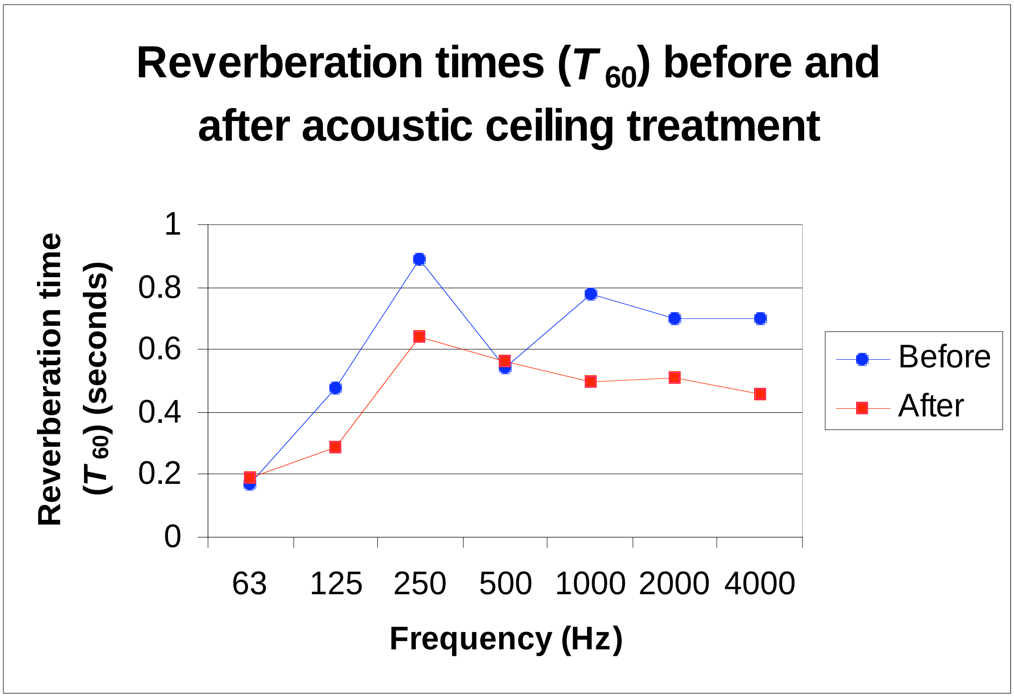
a) Main area before and after acoustic ceiling treatment

Hz	T_{60} (before ceiling treatment)	T_{60} (after ceiling treatment)
63	0.17	0.17
125	0.29	0.47
250	0.71	0.52
500	0.95	0.68
1000	0.90	0.62
2000	0.84	0.56
4000	0.80	0.55

(b) Music area before and after ceiling treatment.

Hz	T_{60} before ceiling treatment	T_{60} after ceiling treatment
63	0.16	0.19
125	0.48	0.29
250	0.89	0.64
500	0.54	0.56
1000	0.78	0.50
2000	0.70	0.51
4000	0.70	0.46

Figure 10-6 Graph of reverberation times for Table 10-9b Case 2

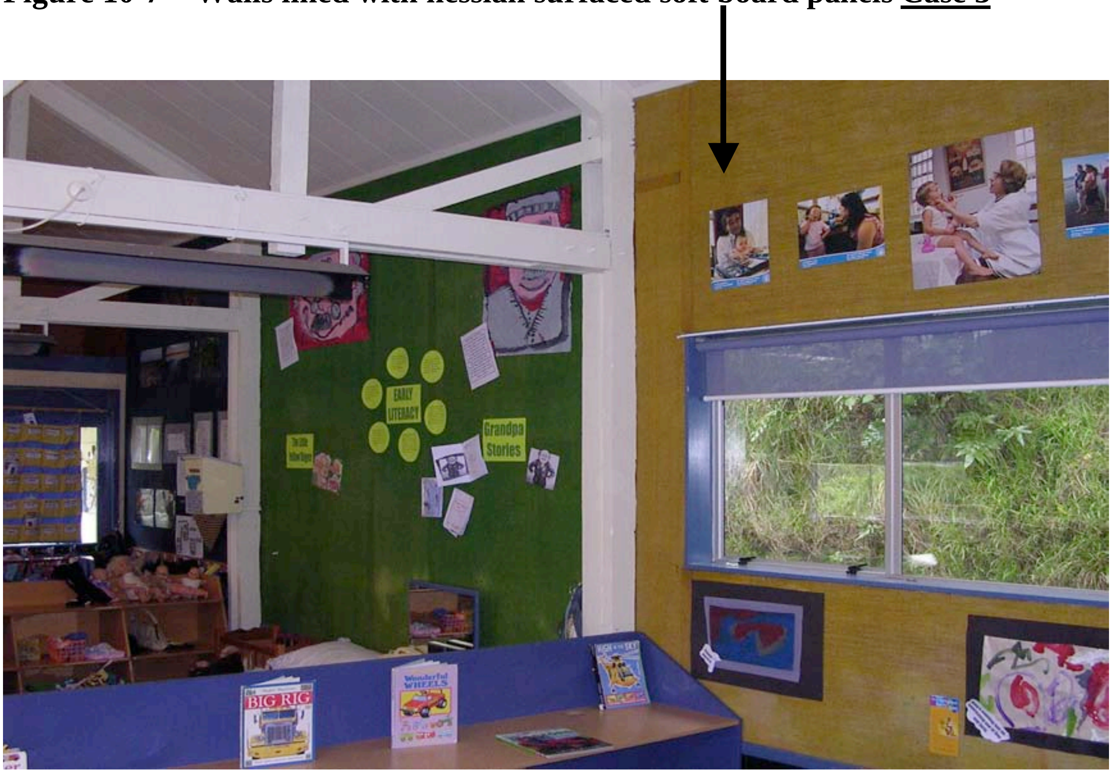


As can be seen in Figure 10-6, acoustical treatment of 50% of the ceiling area resulted in substantial improvement, with as much as 0.3 seconds achieved in the critical frequencies (500, 1000, 2000 Hz).

Case 3

The staff undertook this task of acoustic treatment themselves. Unfortunately the reverberation times carried out before treatment had to be discarded and when the repeat measurements were carried out, treatment had been completed. This centre was very similar in style to the one shown in Case 2 with a pitched ceiling and exposed trusses. This centre, like that in Case 2, generated a number of complaints from staff. While it cannot be firmly established, it is reasonable to assume that reverberation levels could have been in the order of those recorded in Case 2 being a centre of similar construction. These assumed values* (from Case 2) are given for comparison.

Figure 10-7 Walls lined with hessian surfaced soft board panels <u>Case 3</u>



The staff placed dyed hessian covered soft pinex boards over much of the wall surfaces throughout (as shown in Figure 10-7). The reverberation times recorded are given in Table 10-10 and presented as a graph in Figure 10-8.

Table 10-10 Reverberation times(T_{60}) for room in Figure 10-7 Case 3

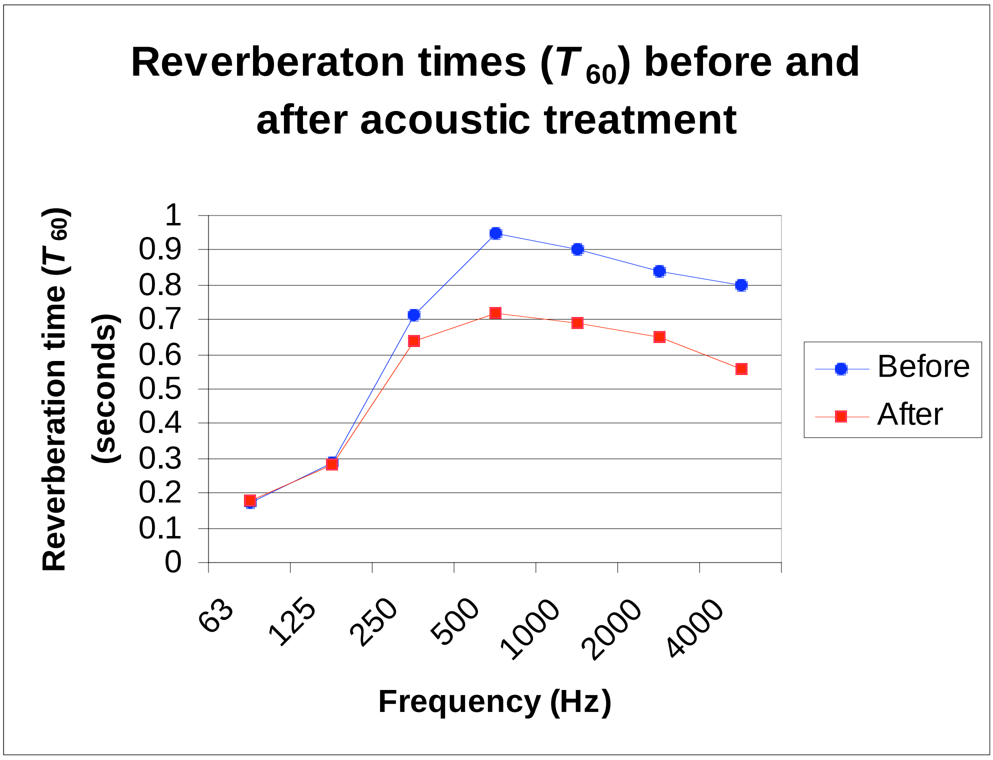
a) Main area

Frequency Hz	*Assumed T_{60} (before treatment)	T_{60} (after wall treatment)
63	0.17	0.18
125	0.29	0.28
250	0.71	0.64
500	0.95	0.72
1000	0.9	0.69
2000	0.84	0.65
4000	0.8	0.56

b) Rear area (near office)

Frequency Hz	*Assumed T_{60} (before treatment)	T_{60} (after wall treatment)
63	0.16	0.16
125	0.48	0.07
250	0.89	0.55
500	0.54	0.63
1000	0.78	0.64
2000	0.7	0.58
4000	0.7	0.52

Figure 10-8 Graph of reverberation times (T_{60}) in Table 10-9(a) Case 3



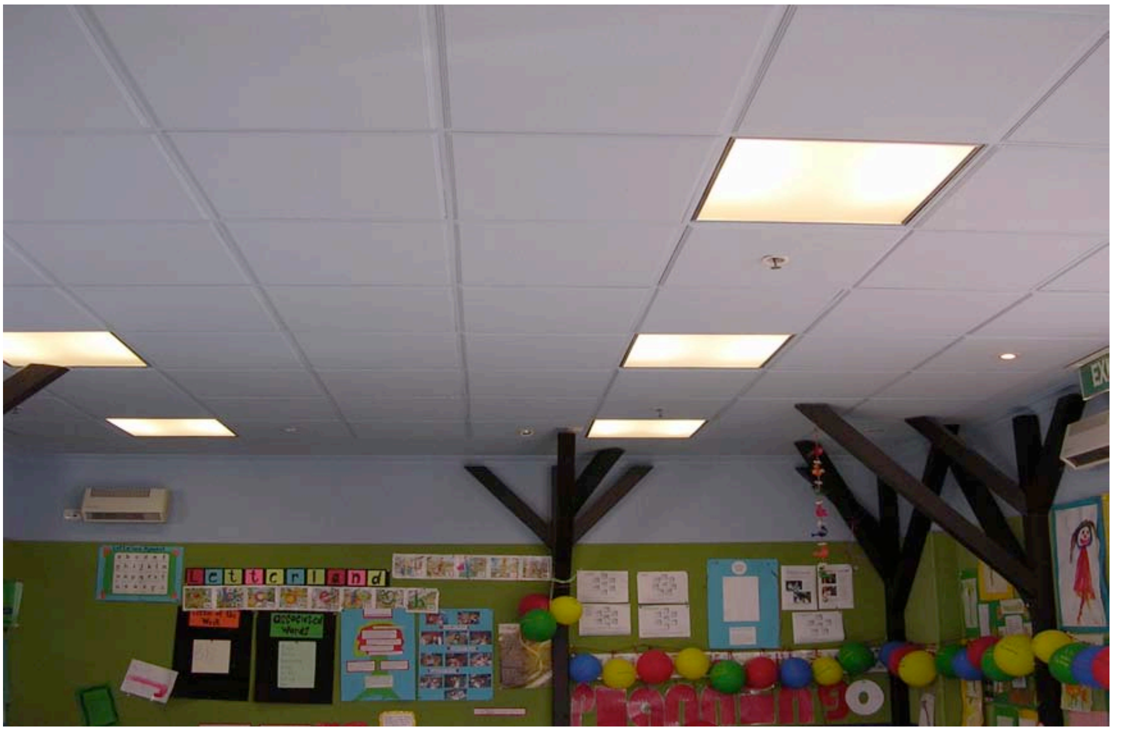
While original reverberation times cannot be known with any certainty, it is reasonable to assume from observations that a significant improvement in the acoustical environment had been achieved although reverberation times are still too high.

Case 4

During a building safety inspection, the inspector required the removal of much of the decorative clouds hanging from the ceiling due to fire risk. Staff were of the opinion that the removal of this material degraded the acoustical conditions of the learning space.

The centre had a suspended ceiling in which ceiling panels, lights and a fan heater were inserted. The frame ceiling tiles had been painted over when the interior was redecorated. Due to the existence of the suspended frame, the governing body were investigating the removal of the existing tiles and replacement with an acoustic tile to reduce reverberation. (See Figure 10-9 below)

Figure 10-9 Ceiling tiles painted over (Case 4)



The reverberation times in the above centre (Figure 10-9) are given in Table 9-11 (below).

Table 10-11 Reverberation times in main room (Case 4).

Frequency (Hz)	T_{60} (main room)
63	0.17
125	0.31
250	0.61
500	0.61
1000	0.55
2000	0.53
4000	0.48

While it is always desirable to gain professional advice, it has been shown that simple applications (Cases 2 and 3) can be effective in at least improving the acoustical environment, even if not meeting the optimum conditions. Wilson et al [1] has shown that the application of a suspended acoustic tile ceiling in school classrooms can result in considerable improvement. However, there are DIY options that can be considered. One option worth considering is fitting of perforated ceiling panels, which can be purchased at a hardware merchant and attached by adhesive to the underside of the existing ceiling. As an alternative, acoustic tiles can be made into panels, which are then suspended from the ceiling. Other options include the lining of the walls with soft board as has been demonstrated in Case 3. Carpeting of areas is also known to reduce reverberation, but is not suitable in many areas likely to become wet or soiled with spillages.

10.3 Summary

Many of the observed early childhood centres were established in existing buildings although there was some purpose built facilities. Many of those observed were stand-alone facilities placed in a number of localities such as residential zones, the Wellington Central Business District, and in school, tertiary institute and church campuses. The number of children and teachers present were very much related to the prescribed requirements of the current legislation.

Poor acoustics such as excessive reverberation times did not always generate complaints from staff. If other teaching aspects were perceived as good, staff tended not to notice poor acoustics. However if the other teaching aspects such as lighting, inadequate space or overcrowding were evident, staff appeared to be conscious of poor acoustics as well.

Few centres had existing acoustic treatment. In some cases acoustic ceiling tiles had been painted over during redecoration. With the increased awareness that this work has created, three centres undertook major acoustic treatment of the walls or ceiling surfaces. In 2 of these cases, reverberation times measured before and after treatment showed a marked reduction of up to 0.3 seconds in the important frequencies. In the third centre, the staff undertook the acoustic wall treatment themselves and due to a failure of the initial test method, reverberation times before the treatment were not available. An estimation of the likely reverberation time before treatment suggests that there may have been a noticeable improvement.

It is essential that all new centres are designed to an appropriate standard to create the best acoustical learning environment for young children. With the adoption of a proposed addition to the New Zealand Building Codes, all new centres would have to meet the appropriate acoustical standard.

Due to scarce resources, it is not possible for many existing centres to engage professional advice to carry out acoustic treatment. However there are DIY (do it yourself) options, which if carried out will result in improvement even if not reaching the optimum level as demonstrated by one centre. An information pack informing the early education sector of options to improve the acoustic environment, which should include DIY options, is highly desirable.

10.4 References

1 Wilson, O., Valentine, J., Halstead, M., McGunnigle, K., Dodd, G., Hellier, A, Wood, J, Simpson, R., *Classroom acoustics, a New Zealand Perspective.* 2002: Oticon Foundation in New Zealand.

2 Education (Early Childhood Centres) Regulations 1998. (New Zealand).

3 Australian and New Zealand Standard, *A/NZS 2107:2000, Acoustics: Recommended sound levels for building interiors.* Standards New Zealand, 2000.

4 Autex Industries Ltd., *Product Specification for Vertiface Compostion Acoustic Wall Covering.* 2006, Autex Industries Ltd , (www.autex.co.nz).

11 Occupational hearing issues of staff

11.1 Introduction

Occupational hearing loss is always of concern in noisy work environments. Personal sound exposures of staff reported in Chapter 8 have showed 13% of the staff assessed received daily sound exposures above the 100% maximum dose levels permitted by the New Zealand health and safety in employment legislation.[1]

The aim of this section was to investigate the direct effects of noise encountered during the working day on the temporary threshold shift of participants and to give an indication of the hearing status of these individuals.

Regulation 11 of the *Health and Safety in Employment Regulations 1995* requires an employer to take all practicable steps to ensure no worker is exposed to sound pressure levels greater than:

- *A time-average level over an 8-hour working day of 85 dB A ($L_{Aeq\ 8h}$ = 85 dB) or equivalent.*
- *A peak level (L_{peak}) of not more than 140 dB*

A code of practice, promulgated under the New Zealand *Health and Safety in Employment Act 1992*[2] for the management of noise in workplace,[3] gives a statement of preferred work practices and guidance in meeting the requirements of the legislation. While the legislation applies to all workplaces, it was never envisaged that the provisions relating to noise in the legislation itself or the code of practice would apply to schools and early education environments.

Noise is regarded as an occupational hazard under the Act.[2] The employer is required to identify, regularly assess and monitor hazards in the workplace (Clause 7). In the case of hazards found to be significant to employees, the employer is required to take all practicable steps to eliminate the hazard at source (Clause 8). If there are no practicable steps that can be taken, the Act proposes that the worker be isolated from the source of noise (Clause 9). If either the source of noise cannot be eliminated or isolated, the employer is required to minimise the noise hazard to employees and this includes the provision of protective clothing (hearing protectors in the case of noise) and monitoring of the employee's exposure to the hazard (Clause 10).

It is clear that this legislation was never designed to regulate noise exposure for teachers in school or early education. One would see the children being isolated from their teachers, or the teachers having to wear hearing protectors. The current legislation[1,2] and code of practice[3] would need major amendments to cover noise exposure for teachers in early education and school teaching environments.

In assessing a noise hazard, the former Occupational Safety and Health Service of the New Zealand Department of Labour stated that apart from personal and environmental monitoring of noise levels, a simple rule-of-thumb method can be used as a general rule (in smaller workplaces). It is generally accepted that a noise hazard exists if:[4]

1. There is difficulty in communication while in the noise.
   (A more formal statement of this is that if the voice has to be raised to carry on a conversation with a person about 1 metre away, then the A-frequency weighted noise level is higher than 85 dB.
2. There is ringing in the ears (tinnitus) after exposure to the noise; or
3. Hearing seems muffled after leaving a noisy area.

Numbers 2 and 3 above relate to the response of the ear to excessive noise exposure. Tinnitus is defined as is a subjective sensation of noise in the ears or head. It can include various descriptions such as whistling, ringing, hissing or buzzing. Tinnitus in this circumstance is a clear warning sign of impending hearing damage. A person does not have to experience tinnitus to suffer noise-induced-hearing-loss.[3]

Temporary threshold shift (TTS) occurs after exposure to noise and is defined as the increase in the threshold detection of sound. A person with TTS notices a dullness or muffled effect of sound as well as experiencing a difficulty in hearing or speech discrimination in background noise.[4]

TTS may also be an early warning sign of impending damage. It can be determined by pure tone audiometry.[1] An audiogram is taken after a quiet rest period, which is usually at the start of the working day or shift (pre-exposure). Following occupational exposure to noise, the audiogram is taken again (post-exposure) and compared to the 'pre-exposure' audiogram. Any significant raising of the hearing detection levels can be regarded as a TTS.

The New Zealand Department of Labour[4] suggests that a TTS may include small intracellular changes in the sensory hair cells of the cochlea and swelling of the auditory nerve endings as well as metabolic exhaustion of cells.

Hearing will return to the normal threshold level from a TTS, provided that sufficient time is allowed (can exceed 48 hours) for recovery, which depends on the intensity and duration of the sound. Where further exposure to noise occurs before full recovery can occur, the threshold shift may become a permanent threshold shift (PTS), which is noise-induced-hearing-loss. For this reason an assessment of TTS and noise exposure is an indication of potential hearing damage.

11.2 Experimental

The aim of this section was to directly assess the effects of noise encountered during the working day on the temporary threshold shift of hearing as well as investigate the current status of hearing among participants. Audiograms were taken from 20 participants with the current Standardized procedure for presentation of tones prior to the start of the working day to establish the normal hearing threshold of each participant. A personal sound exposure meter or doseBadge was fitted to each staff member to monitor noise exposure during the working day. At the end of the working day the personal sound exposure device was removed and a second audiogram using the same standardized procedure was taken to determine any TTS and to relate this to the personal sound exposure level. A screening audiometer (GSI17) was used and audiometric testing was done either at Massey University or at the particular early childhood centre. A standard testing booth was not available.

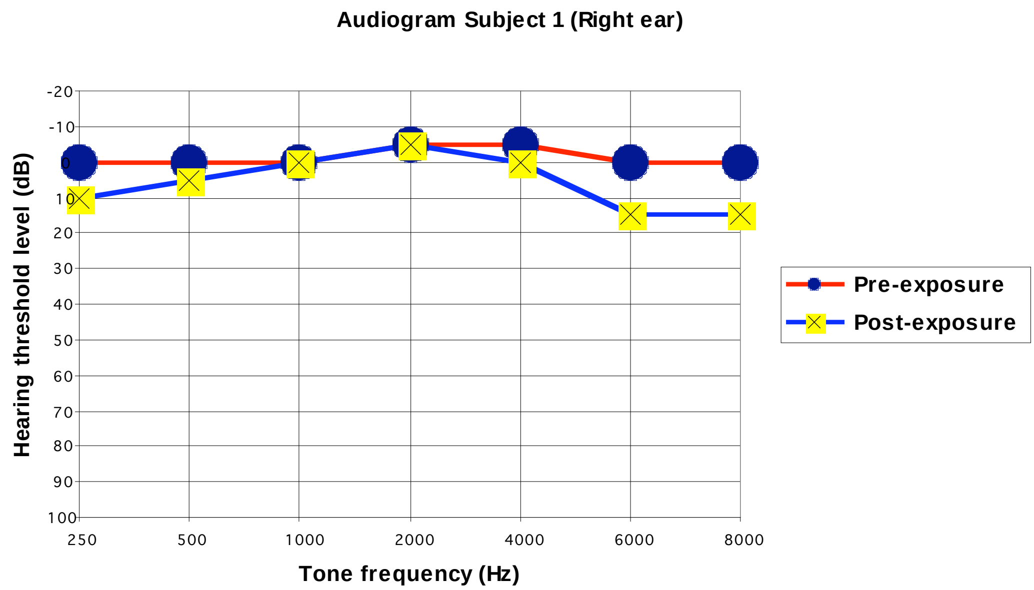
[1] Examples of audiograms for normal hearing and Noise-Induced Hearing loss are given in 6.2-Hearing impairment and deafness (Chapter 6)

11.3 Results

Background noise presented major issues in conducting the audiometric testing. Even though the Massey University space was normally very quiet, the noise of heavy rain on the roof and water running down gutters became a major source of distraction. There were major difficulties in detecting the tones in the lower frequencies probably due to masking effects. The other 2 centres wished to have their evaluations done on the premises, but no quiet space was available and with staff rosters, 10 of the tests had to be done while children were present with the noise presenting a major source of distraction. In addition, time was constrained with staff having limited time available before commencing duties. These two environmental factors together with the lack of a testing booth, compromised reliability. However the results were useful as participants who had not consulted an audiologist or audiometrist, were able to gain an approximate status of their hearing.

A participant who reported comforting distressed children close to her ear had a noticeable increase in the hearing threshold of the left which was closest to the children when she held them. The incidents had occurred later in the day. The audiograms are given in Figure 11-1. The overall dose was 70% for the full working day but the time history (shown in Figure 11-2) showed higher levels received in the latter part of the working day. This participant, a young female worker of 20 years of age had very good hearing from the audiogram taken at the start of the day. By the end of the day despite the environmental difficulties, the threshold for the left ear lifted significantly in the frequencies of 2,000, 4000, 6000, and 8,000 Hz. The was a smaller but similar rise in the frequencies of 4000, 6000, and 8,000 Hz for the right ear.

Figure 11-1 Audiograms of a worker pre and post exposure to noise



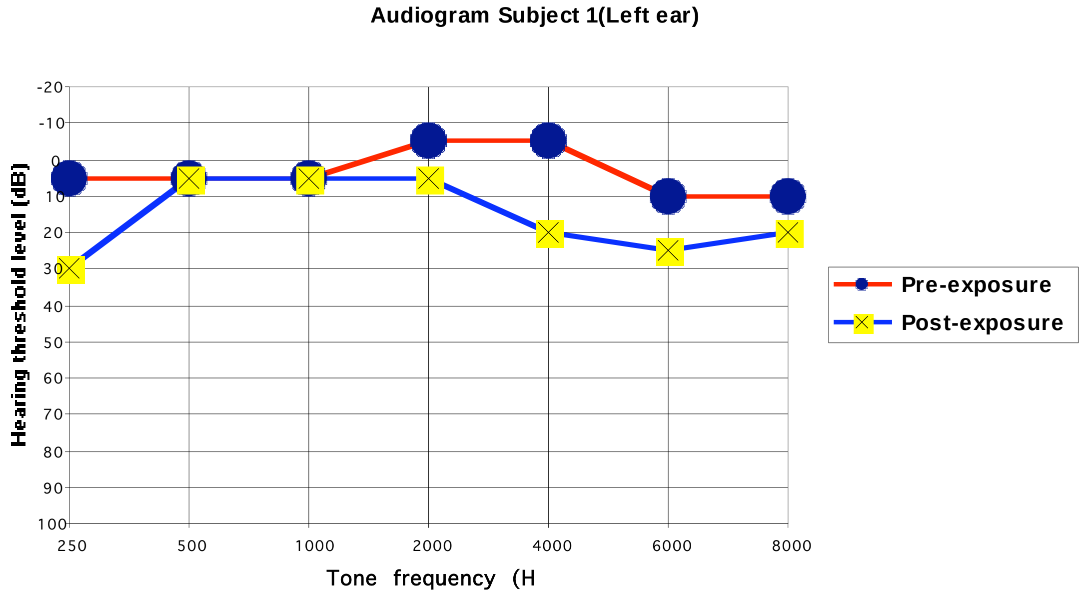
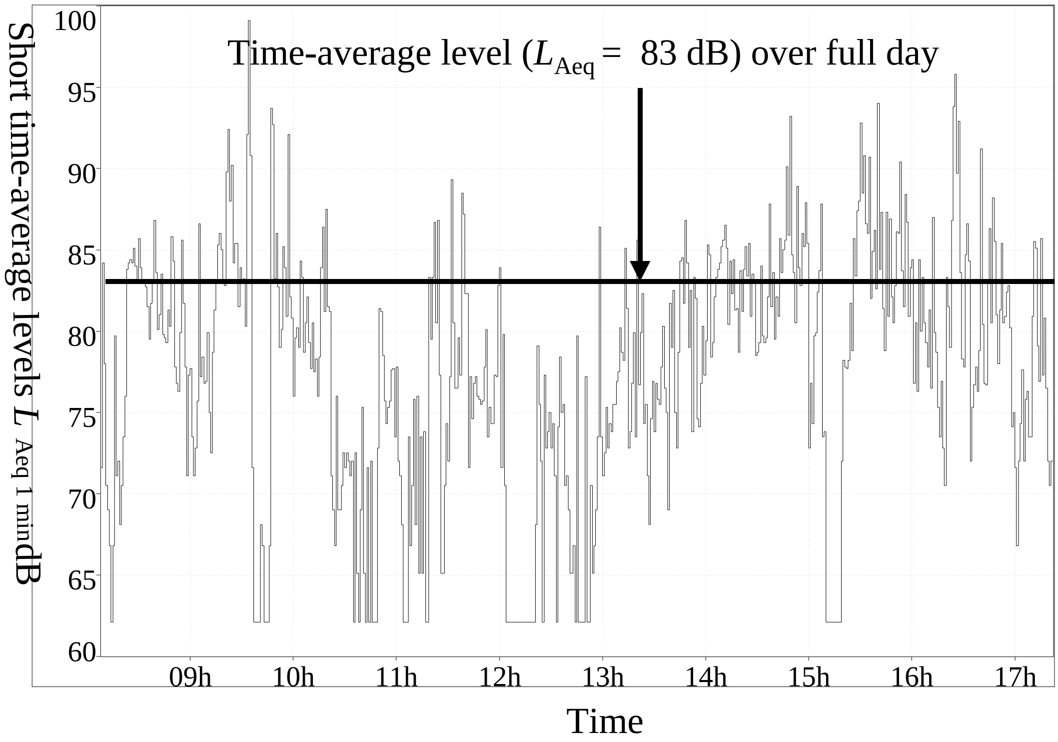
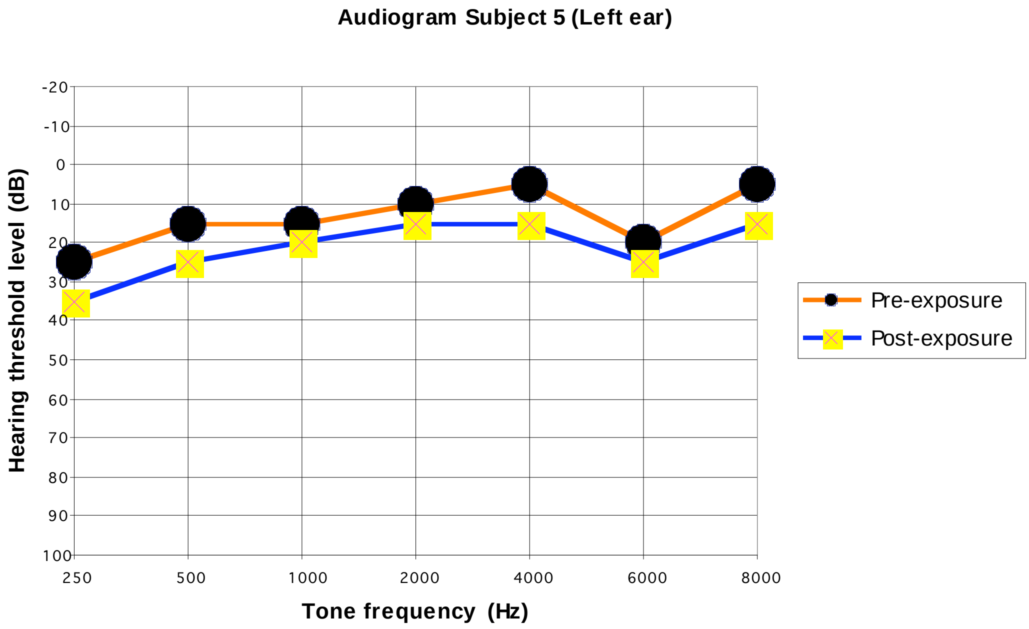


Figure 11-2 Time history of a worker experiencing TTS.



Another staff member in the same centre had a smaller overall noise dose of 35%, which is well within the maximum of 100% dose permitted in the workplace over a working day. From the doseBadge readings, the work period through the morning up to 1.30 pm was very quiet. In the afternoon there were 2 noisy periods from 1.40-2.40 pm with an A-frequency weighted time-average level of 85 dB for the hour duration and a small party from 3.25-3.50 pm with amplified music, which measured an average of 89 dB for the 25 minute duration. There was a small rise in the threshold levels (5-10 dB) across all frequencies in the left ear but this was still within the margin of error as shown in Figure 11-3. Staff fatigue at the end of a long working day was also evident and this could have had a bearing on the results.

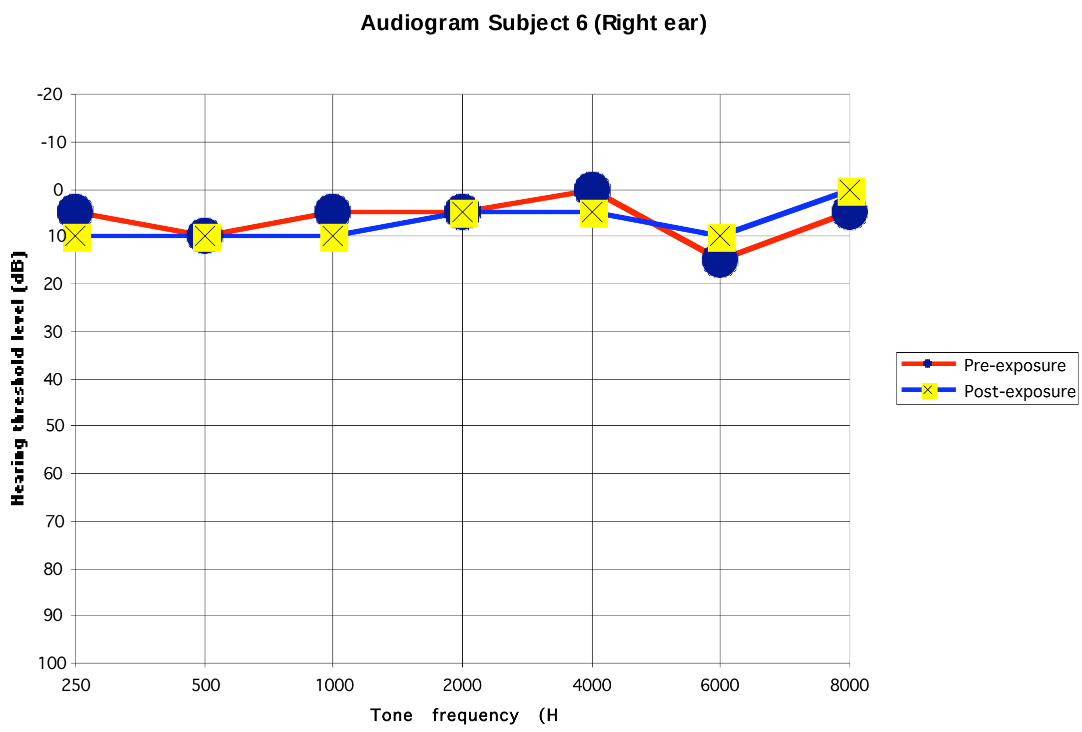
Figure 11-3 Audiogram of staff worker exposed to short bursts of noise

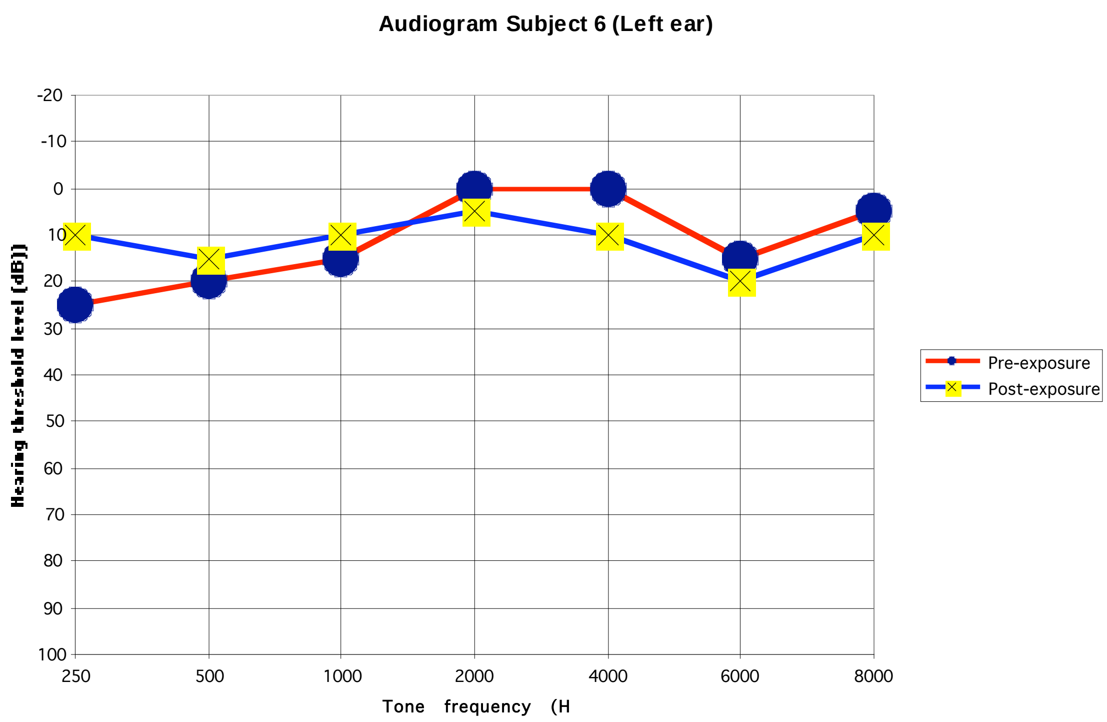


Half of those tested showed the likelihood of developing noise-induced hearing loss, which is characterised by an increase in the threshold values in the 4000- 6000 Hz frequency range (or the 'characteristic notch' at these frequencies)*. In the younger teaching staff, noise-induced-hearing-loss was often not evident from their audiograms. An example is given on Figure 11-1 with a staff member aged 20. A minor or emerging notch was observed in some participants aged in the 30–35 age bracket as shown in Figure 11-4.

* Information on noise-induced hearing-loss and examples of audiograms are given in chapter 6 (page 6-2).

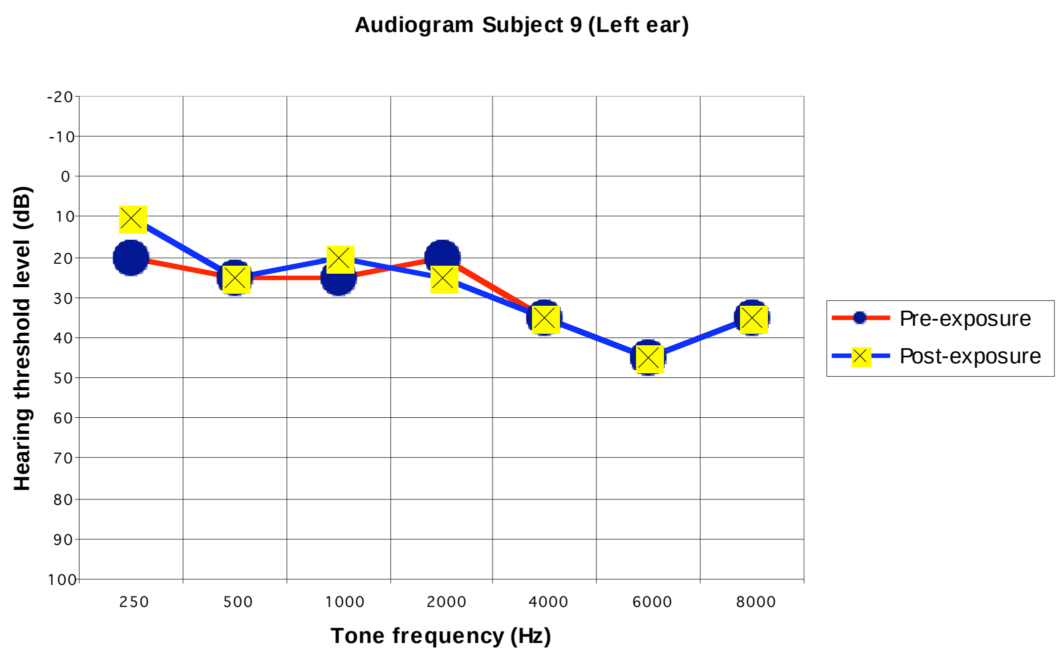
Figure 11-4 Audiograms of a staff worker aged in the 30-35 age group.





There was a trend of increasing levels of hearing loss as participant's age increased as shown in Figure 11-5 of a teacher in the 40-45 age group.

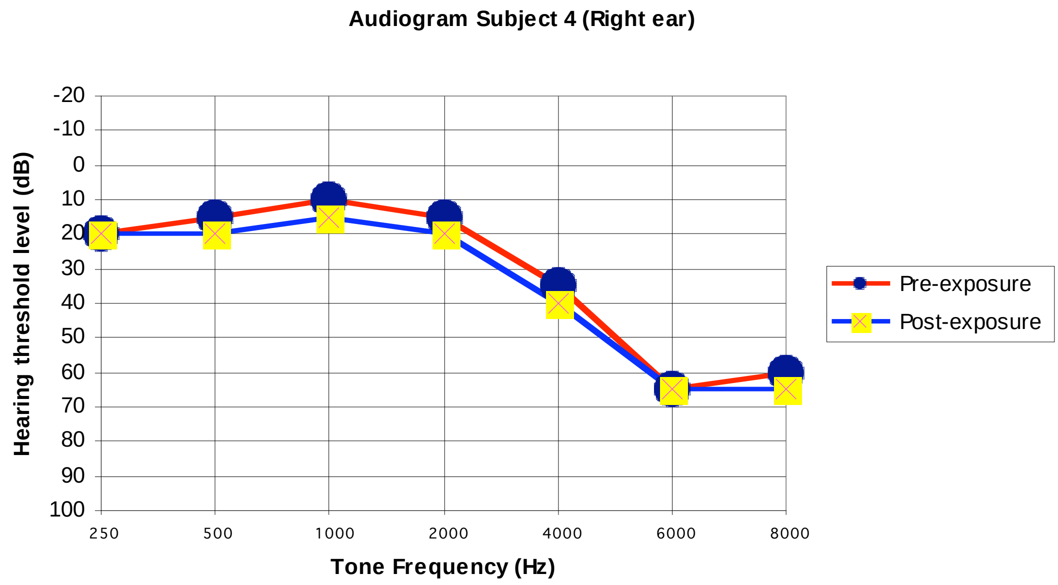
Figure 11-5 Audiogram of a staff member in the 40-45 age group.



Finally a staff member in the 60-65 age group had the audiogram shown in Figure 11-6. Although there did appear a small movement in TTS due to noise exposure this was within the margin of error. While those in this age group will have a significant contribution from presbycusis superimposed with hearing loss due to other causes, it would be of concern if this level of hearing loss was representative of this age group of teachers in early education.

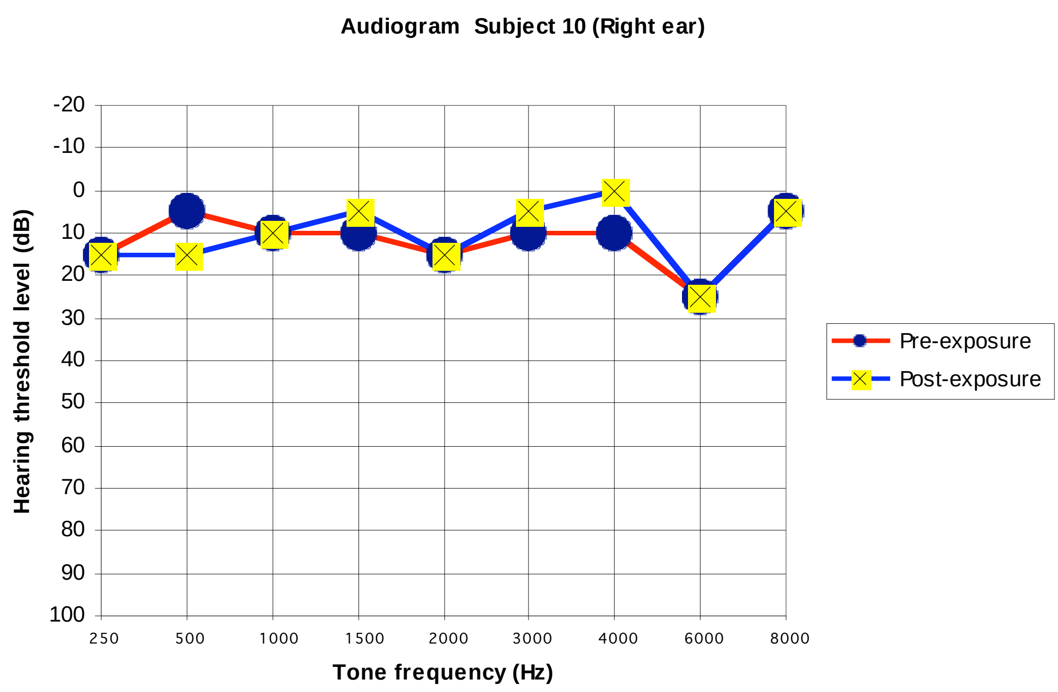
Further investigation is urgently needed to determine the extent of hearing loss, which exists in teachers of the early education sector and the amount that can be reasonably attributed to occupational exposure.

Figure 11-6 Audiogram of staff member in the 60-65 age group.



Most of the audiograms did not show significant differences between pre-exposure and post exposure levels. One staff member listened to loud music in the car on the way to work and after having her first audiogram taken in a noisy environment, had a reasonably quiet working day with a daily sound exposure of 31% dose. The test condition at the start of work was difficult as this teacher was on the last shift arriving at 9.30 am when all the children were present but at the end of the working day when the subject was retested, all the children had departed and the testing condition was very much quieter. The audiograms for the right ear are shown in Figure 11-7.

Figure 11-7 Audiogram of staff member (on last shift)



It was interesting that 2 staff members showing higher dose values 150 and 98% only showed a small TTS. However it seems that with the levels experienced in this study recovery was able to occur in a short time. Those that showed higher exposure to noise just prior to having the second audiogram also showed a small TTS.

11.4 Conclusion

The results from this study were far from conclusive with significant environmental factors such as interference and masking from background noise, time constraints and lack of a suitable testing booth, presenting significant obstacles in obtaining reliable audiograms. Whilst there did seem to be a slight increase in hearing threshold values after work from the of the participants across the frequencies, all but one of these (given in Figure 11-3) were within the margin of error. However, the personal sound exposure rates recorded on staff during the full study and the information gained from this part of the study suggests that this is an important occupational issue for teachers in early education environments. A dedicated study is now needed to establish the levels of hearing loss among teachers and contact staff in the early education sector and to reasonably establish the extent of hearing loss due to occupational exposure when compared to other activities outside work, which contribute to noise-induced hearing loss. This must include the availability of suitable quiet testing spaces if testing booths are not available.

The New Zealand Department of Labour has largely ignored this group of workers as being at-risk from excessive noise exposure at work, and this now needs immediate attention. It is of considerable importance to investigate thoroughly the extent of occupational noise exposure with this group of workers, and to implement regular testing programmes as is done with other at-risk workers. It may be necessary, based on establishing the level of risk among these workers, to propose amendments to address occupational noise issues in the legislation[1,2] and the associated code of practice[3] as applicable to this profession.

11.5 Recommendations

- A wide ranging national study be undertaken of child contact workers such as teachers workers across the early education sector to establish levels of hearing loss attributable to the work environment.
- The New Zealand Department of Labour and the Ministry of Education ensure that regular testing programmes are introduced for occupational hearing loss and noise exposure among early childhood staff.
- Governing bodies introduce appropriate policies on mitigating noise exposure for the staff as well as children, and provide opportunities for all staff to undertake regular hearing evaluations.

11.6 References

1 H*ealth and Safety in Employment Regulations 1995* (New Zealand legislation)

2 *Health and Safety in Employment Act 1992* (New Zealand legislation)

3 Occupational Safety and Health, *Approved code of practice for the management of noise in the workplace*. 2002, Wellington: Occupational Safety and Health, New Zealand Department of Labour.

4 Occupational Safety and Health., *Noise-induced hearing loss of occupational origin: A guide for medical practitioners*. 1994, Department of Labour : Wellington, New Zealand.

12 A new regulatory framework

12.1 Introduction

The New Zealand Ministry of Education has been conducting a major review of the Early Childhood legislation, which has progressed concurrently with this work. In the initial consultation with stakeholders, noise was identified as a major issue which had to be attended to.[1] The Ministry of Education's Criterion Development Team sought advice as to how noise could be regulated in early childhood centres with current resources and personnel. If a standard criterion was to be promulgated, it had to be able to be assessed and with the current level of resources.

McLaren and Dickinson[2] prepared a report for the Ministry of Education to discuss the options available for regulation of noise in early education. In considering the options available, existing legal precedents were examined, resource requirements considered, and the effects on children in general reviewed with special consideration given to the most at-risk children.

12.2 Noise provisions of the current legislation

Regulation 22 of the *Education (Early Childhood Centres) Regulations 1998* states:

> *The licensee of a licensed centre must ensure that every room in the centre that is used by children has, to the satisfaction of the Secretary, adequate natural or artificial lighting, adequate ventilation, acoustics that ensure that noise is kept at a reasonable level, and adequate heating.*

The above regulations do not define what is considered to be a reasonable (or unreasonable) level of noise.

Legal and practical uncertainty exists when criteria are defined as meeting the *satisfaction of the Secretary* if the Secretary (of Education) has not clearly documented what outcomes will meet his satisfaction.

There are some noises intruding from outside the centre that would be completely outside the control of early childhood centre or governing bodies. This was demonstrated with the well known eradication of the painted apple moth in the Western suburbs of Auckland, New Zealand with the low flying of aircraft over schools and early education centres in the spray zone. In addition, construction sites with activities such as pile driving and jack hammering can be very noisy, very disturbing and distressing for some children if noise from these activities is not properly controlled.

Regulation 22 fails to address the effects of noise on special needs children, as highlighted in Chapter 9.

The Ministry has recognised the difficulties for both its staff and practitioners in properly interpreting descriptors frequently occurring in the current regulations such as *adequate, reasonable, suitable* or to the *satisfaction of the Secretary*. Without a legally enforceable set of standards or rules, judgements often have to be made on a case-by-case basis. The Ministry of Education has proposed a third level tier to the new legislative model to overcome these issues as discussed in Section 12.4 on page 12-7. This will be placed under a new set of regulations and should achieve greater national consistency in early education outcomes.[3]

12.3 Noise sources and issues

This issues related to noise in early childhood education centres can be divided into the following broad categories:

- Noise transmitted through or reflected by the building structure
- Noise generated as part of the centre activities
    - Noise from children themselves (while engaged in play, when distressed etc.)

  - Noise from the use of equipment, fittings, toys, hi-fi, musical instruments etc.
- Noise intrusion from activities outside the centre (over which the centre often have little or no control)
- Protection and rights of special needs children known to be adversely affected by noise who are mainstreamed in early childhood centres. This includes children with middle ear infections, hearing impairment, auditory processing disabilities and sensory integration disorder.
- Lack of quiet spaces
- Excessively noisy fire alarms

To answer these issues and to establish a protocol for providing the best practicable environment for children and staff in early education centres, the following recommendations are proposed:

- The building should be designed to meet an acceptable acoustical standard with a reverberation time (T_{60}) of 0.4-0.6 seconds in the octave-band frequencies of 250-4,000 Hz.
- Noise generated in the centre needs to be managed to achieve predetermined outcomes. This can include the management of noise to a level which does not interfere with normal speech or communication. In addition, provision for the most at-risk children needs to be considered.

12.3.1 Noise transmitted through or reflected by the building structure

The building must be so designed and constructed that it will attenuate any excessive noise generated outside to a level that inside will not be intrusive to learning. Children usually do not have the skills to process words lost in noise. The features of building design will be given in the New Zealand Building Code and need not be further discussed here.

12.3.2 Management of noise generated as part of the centre activities

There is precedent for 2 options in a legislative framework.

12.3.2.1 Setting of sound pressure level standards

In this prescriptive approach, sound pressure level criteria using appropriate noise descriptors are established and all centres would have to take reasonable steps to comply with the criteria. This would include time-average level limits (measured in decibels). To implement this strategy, considerably more resources would be needed than are currently in use. If sound pressure level limits are to be established, it would mean that sound pressure level measuring equipment would be required to assess compliance, along with officers competent in noise measurement techniques. In addition to the purchase of equipment, there are ongoing maintenance costs and regular calibration of the equipment.

One of the most difficult obstacles to adopting this approach is the lack of an appropriate standard for measurement and assessment of noise in early educational settings. In developing a standard, the following would have to be considered:

- Are sound pressure levels to be measured using fixed sound level meters mounted in such a way to obtain representative samples while not obstructing the free flow of movement around the centre? This would usually mean the use of a microphone on an extension cable from the sound level meter and suspended from the ceiling, beam or other such structure in the middle of the teaching space to minimise reflections etc., from the walls as carried out in this work. In theory, sound should be measured in the hearing zone (height of the children and teachers' ears) but practicalities preclude this option due to the obstruction of movement and the possibility of damage and interference from tampering etc. The microphone would therefore have to be set at a height above the normal hearing zone.
- Are individual personal sound exposure measurements to be carried on staff and children? This work has trialled the recently introduced noise doseBadges on staff and children in early childhood centres. Grebennikov[4] has also carried out a study on preschool teacher exposure to noise with this equipment. While the

use of this equipment has given valuable information over the levels of personal sound exposure received by children, there is a considerable amount of preparation required including informed consent of parents to fit these devices to the clothing of their children. Depending on the activities of children, results can vary greatly.

- Accounting for variables such as weather will need consideration. Weather can have an effect on sound pressure levels. During fine weather, children are likely to spend considerable time in outdoor play areas, while inclement weather will confine children indoors.

- Sound pressure levels do not take account of the nuisance value of particular noises. Some sounds do not need to be loud (high sound pressure levels) to be very disturbing. Sounds such as sirens, whistles, barking dogs and sharp impact type sounds can be very intrusive and disturbing. Depending on the frequency characteristics, some sounds will interfere and mask speech far more than others at the same sound pressure levels.

- How will the special needs of children adversely affected by noise be addressed such as those experiencing sensory integration disorder?

The main advantage with this approach is that it will give a national standard with which all must comply. It would however, take a considerable level of consultation to arrive at a consensus over what criteria will be ideal in order to incorporate the large variety of early childhood facilities into such a one-fits-all standardised approach. The other main concern is that enforcement would have to be carried out by sound level measurement against the criteria. As enforcement obviously cannot be done in secret, it would be natural for centre staff to manipulate activities and sessions to minimise noise when monitoring was occurring. This would not give an accurate assessment of the situation. It may also be detrimental if certain beneficial activities were curtailed for fear of exceeding a prescribed limit.

12.3.2.2 All practicable steps model

In this framework, sound pressure level criteria are completely dispensed with. The focus is instead on outcomes, with staff identifying noise issues within their centres and then formulating a plan to manage these.

Rather than prescribing sound pressure level criteria, the outcomes to be achieved by controlling noise need to be identified and built into the criteria. In addressing this, we need to consider the negative aspects that noise is likely to have on the children and teachers. Some of these are:

- Hearing damage to the children if personal noise exposure is excessive.

- Interference with speech and communication. This can degrade the dissemination of information and enhancement of socialisation skills.

- Damage to teachers' hearing if sound pressure levels exceed the internationally accepted occupational criteria (as defined by *Regulation 11* of the New Zealand *Health and Safety in Employment Regulations 1995* of:
    - *An A-weighted time-average level of 85 dB over an 8-hour working day or equivalent. That is a maximum of 1.0 pascal squared hour in acoustical terms or 100% dose ($L_{A\ eq\ (8\ hour)}$ = 85 dB).*
    - *A peak level (unweighted) of no more than 140 dB** *(L_{peak} =140 dB).*

- Voice strain of teachers from having to raise voices. This is likely to affect the most, those with softer voices, who have to raise their voices to be heard over the noise made by children and their activity.

- The effects of noise on special needs children known to be adversely affected by noise.

Unlike the alternative framework of setting sound pressure level criteria, the *all practicable steps* model can be implemented with current resources and structures as it is based on subjective judgments to meet a predetermined set of goals or outcomes.

* 'Peak Level' is a specific acoustical measure and is not its maximum sound pressure level value.

Requiring noise to be kept to a level that enables normal speech and communication to occur is one such goal that can be considered. The interference with sleep is an important issue if babies and children are sleeping. Controlling noise levels which distress or harm special needs children is another important outcome or goal in centres where these children are present.

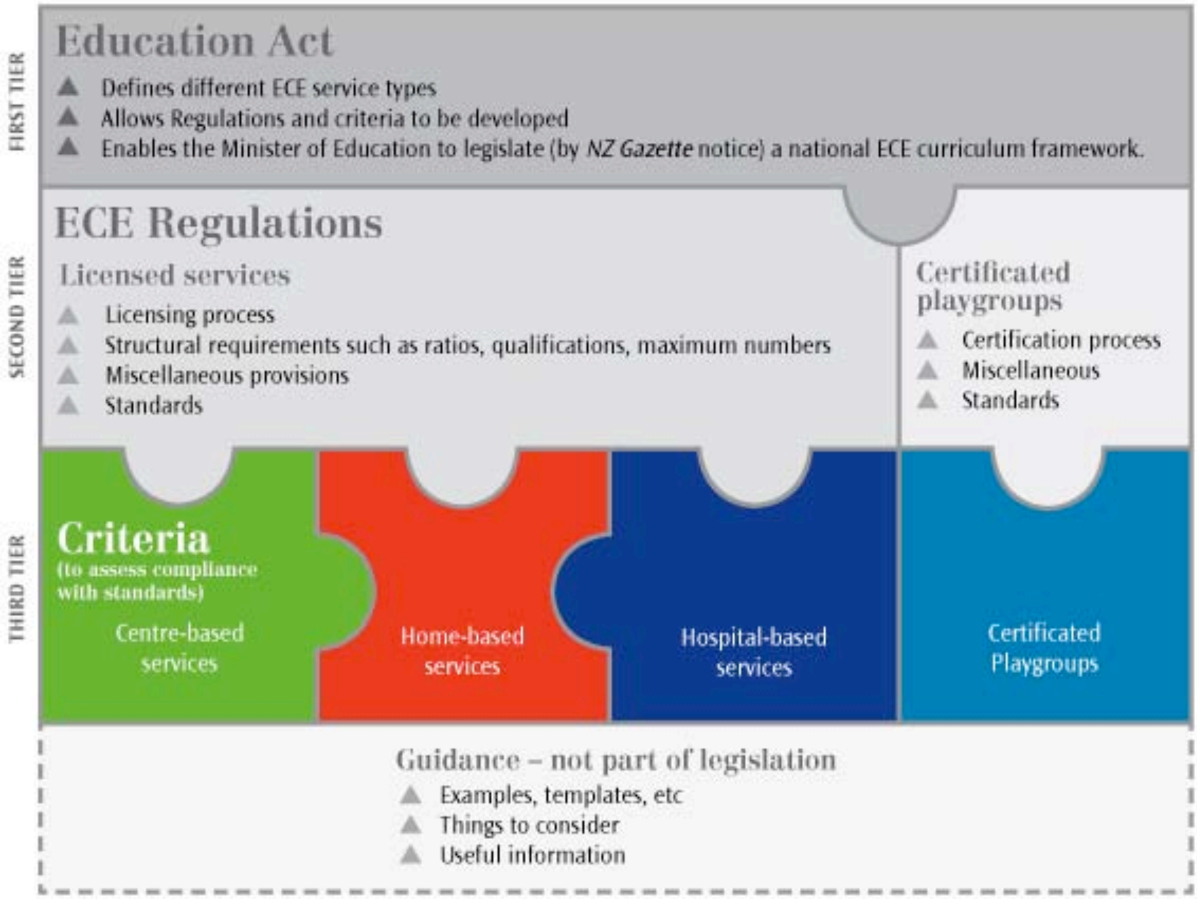
Unlike the setting of sound level criteria approach, this is a far more subjective interpretation, which may seem a disadvantage. The *all practicable steps* model can however, be far more responsive to individual characteristics of centres and their receiving environments, which obviously includes those individuals most seriously affected by noise. The requirements could therefore be quite different for a centre in which special needs children, who are adversely affected by noise, are present against one where there are no such children enrolled.

12.4 The proposed legislative framework

The present legislation in New Zealand for the control of early childhood legislation comprises of 2 levels or tiers. The primary or first level is the *Education Act 1989* and at the second level are the *Education (Early Childhood Centres) Regulations 1998* which are made pursuant to the Act.

The New Zealand Ministry of Education proposes a three level framework, which in effect adds a third level, or tier to the legislation, which will fit under the Act and Regulations as shown in Figure 12-1.[3]

Figure 12-1 Proposed legal framework for licensed early childhood centres (New Zealand)



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The New Zealand *Education Act 1989* has been amended by addition of a new section to cover all early childhood education services. The Act will define the various services types, and permit the development and promulgation of regulations and criteria. A new set of regulations will detail the licensing process, indicating structural requirements (e.g. ratios, qualifications, board standards and miscellaneous provisions such as the role of the Ministry) in the sector.[3]

The New Zealand Ministry of Education (2006) released the *Draft criteria for licensing or certification of ECE (early childhood Education) services: Discussion document* after passing of the second reading in Parliament. The Ministry has embraced the recommendations made by McLaren and Dickinson[2] and adopted the *all practicable steps* model in noise management.

Three principal clauses in the above draft licensing criteria are related to noise and are as follows[3]:

Clause 2.16: *HEATING, LIGHTING AND VENTILATION*

- *Parts of the building used by children shall have acoustic absorption materials necessary to reduce noise levels that may negatively affect children's well-being.*

Clause 2.27: *SLEEP FACILITIES FOR ALL DAY CENTRES*

- *If children under the age of two attend, there is a room available (separate to any activity space) to support the provision of restful sleep at any time they are attending. This room must be able to be closed off from activity areas so that fluctuations in temperature noise and lighting levels can be kept to a minimum.*

Clause 3.20: *NOISE*

- *All practicable steps shall be taken to ensure that noise levels do not unduly interfere with speech and /or communication or cause any children attending distress or harm.*

A number of studies including those by Picard and Bradley[5] and Nelson and Solti,[6] have found noise to be a critical element in effective speech and communication. Excessive noise or noise which masks critical elements of speech perception can have a serious effect on the process of children being able to understand their teacher and other children. Effective speech intelligibility requires a signal-to-noise ratio of 15 dB. In the case of learning spaces the teacher's voice (the signal) needs to be 15 dB above the background noise level. It is a good practical measure to judge noise levels against normal speech and communication. If the teacher has to shout to be heard, then the levels of noise are too high. In addition, the voice when shouting distorts and adds further problems for special needs children A higher signal to noise ratio may be required for children with hearing and auditory processing deficits. The interactive learning space of an early childhood education centre is obviously going to generate noise from free play and learning by interaction of children with each other and their teacher. The challenge for all teachers is to achieve a balance between what is excessive noise and that which is a consequence of children's learning, the participation and enjoyment of the activities. To achieve effective speech communication a teacher speaking at 65 dB would need a background noise level no higher than 50-55 dB. This outcome appears a very practical way to control noise levels. There is some debate over the safe levels of noise for children. The World Health Organization[7] while recognising that more work needs to be done in this area, believes that A-frequency weighted time-average levels below 75 dB are unlikely to cause hearing loss in the majority of the worldwide population. The risk of health issues concerning teachers, such as hearing loss from excessive exposure and vocal strain, is very likely to be reduced from effective control of noise.

Sound-field systems to enhance signal to noise ratios have often proved an effective tool to assist learning in school settings. A number of studies in the use of sound-field technology have found a number of positive outcomes with increased attention to tasks, a higher level of performance against set criteria an improvement in behaviour and benefits for special needs children.[8,9,10] Sound-field systems have not been extensively used in New Zealand mainstream early childhood education. More work and studies on the use and effectiveness of sound-field systems in New Zealand Early Childhood Education Centres are certainly warranted.

Clause 3.20 refers to noise, which could cause children distress or harm. This clause, while very wide reaching, primarily addresses the issues for children with special needs who are adversely affected by noise. The draft criteria aim to offer protection from noise causing distress to a child with auditory problems such as sensory integration disorder, a high-risk group (e.g. autism, Asperger's syndrome and giftedness). This means that practical steps must be taken to protect an autistic child who is overwhelmed and distressed by the level of noise. This will be difficult if the noise is from an external source where the centre has no direct control over the sound. However the taking of *all practicable steps* would mean to take reasonable attempts to have the noise nuisance abated by seeking the assistance of the noise control officer of the territorial authority or even by direct negotiation with the person(s) or organisation making the noise. *All practicable steps* would also include making representations in the consents process under the New Zealand *Resource Management Act 1991* where affected parities are entitled to raise objection to any *notified* consent application, which is going to affect them.

The issue of effective measures to allow restful and adequate sleep was identified by New Zealand Ministry of Education officials in documents and consultation meetings held around the country. Some centres do not have adequate sleeping facilities and when space has become a premium it has been the sleep areas that have generally suffered by being reduced to make way for other activities. Clause 2.27 in effect requires a fully partitioned area (with its own air space) to mitigate the effects of noise disturbing sleeping infants and other affects such as fluctuations in temperature and lighting are kept to a minimum.

Clause 2.16 is relevant where poor acoustic conditions exist such as excessive reverberation times. The current ANZ standard[11] recommends a reverberation time of 0.4-0.6 seconds (250-4,000 Hz octave-band frequencies) for classrooms and learning spaces. In the case of hard reverberant surfaces giving rise to reverberation times which would generally be greater than 0.8 seconds, there would be noticeable effect on speech intelligibility from excessive reverberation. This clause could be used to require the fitting of acoustic absorption or insulation materials to reduce reverberation times to the current recommended level. If a proposed amendment to the New Zealand Building Codes is adopted, all new centres will have to meet the new criteria as part of the building consents process. However the code, while not mandatory for existing centres, would provide a valuable guide in centres to meet the requirements of Clause 2.16 where an unsatisfactory acoustical environment exists.

The ‘Guidance section’ is an innovative addition to the proposed legislative framework. While it is not part of the legislation, it could provide valuable assistance and tools to meet the requirements of each level of the legislation. The Guidance section could be used to provide clear instruction with examples on what constitutes *all practicable steps*. Strategies to manage noise could be included in this section - such as an innovative traffic light system for noise developed by a local kindergarten. The green light indicates that the level of noise is satisfactory. An orange light means it is becoming too noisy and a red light indicates that it is far too noisy and must be reduced. A key strategy would be for centres to develop a noise management plan as part of their operational procedures and policies. A template could be included in the guidance section

The development of a noise management plan is discussed in 14.2 Appendices.

This research identified the lack of quiet spaces and excessively noisy fire alarms as important areas in need of attention. These 2 items have yet to be addressed in the proposed legislation.

12.5 Conclusion

Proposed new legislation for the licensing and control of early childhood education services has recognised issues of excessive noise and the detrimental effects of noise to all children and their teachers, especially those children at higher risk. While no one piece of legislation can in itself fully control noise issues in childcare centres, the proposed criteria present outcome-based solutions to control noise. This has a number of advantages over the prescription of sound levels in terms of being able to be implemented, and encourages staff to take ownership of the issue by incorporating strategies to control noise as part of their teaching practice without fear that they may be exceeding a prescribed limit. The New Zealand Ministry of Education rejected the framework of setting prescribed limits in favour of the *all practicable steps* model for noise to meet important goals such as to enable effective speech and communication and to protect those children distressed and harmed by noise. It will be necessary to also address external noise issues from large construction works, and the territorial authorities, which grant consents, need to be aware of the issues such noise has on children in childcare centres in the vicinity. Impact noise such as pile driving or jack hammering can be very distressing to at-risk children. One way to address this is to propose an amendment to the current New Zealand standard for construction noise[12] which is extensively used in such cases. The other more important option is for early childhood centres to ensure that they actively participate in the consultation process and make submissions on *notified* consents for noisy activities that are going to affect their children. This would allow appropriate conditions to be considered for such operations. The draft criteria do not address the issues involving excessively noisy fire alarms nor the lack of quiet spaces.

12.6 Recommendations

The *Draft Criteria for the Centre-based ECE (Early Childhood Education) services* be extended to give more defined coverage to the following:

- The provision of separate fully partitioned quiet spaces is given further consideration as a mandatory requirement.

- That the criteria specifically address the issue of excessively noisy fire alarms.

12.7 References

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6 Nelson, P.B., Soli, S., *Acoustical barriers to learning: Children at risk in every classroom.* Language, Speech and Hearing Services in Schools, 2000. **31**: p. 356-361.

7 World Health Organization, *WHO Guidelines for community noise*, Berglund, B. Lindvall, T., Schwela, D., Editors. 1999, Occupational and Environmental Health Unit, World Health Organization: Geneva.

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9 Palmer, A., *Quantification of the ecobehavioural impact of a sound-field loudspeaker system in elementary classrooms.* Journal of Speech Language Hearing Research, 1998. **41**(4): p. 819-188.

10 Bennetts, L., Flynn, M., *Improving the classroom listening skills of children with Down Syndrome by using sound-field amplification.* Down Syndrome Research and Practice, 2002. **8**(1): p. 19-24.

11 Australian and New Zealand Standard, *A/NZS 2107:2000, Acoustics: Recommended sound levels for building interiors.* Standards New Zealand, 2000.

12 New Zealand Standard, *NZS 6803:1999, Acoustics - Construction Noise*. 1999, Wellington: Standards New Zealand.

13 Discussion

13.1 Introduction

The early years of life are critical in the development of speech and hearing. Delay or deficits in these vital functions are well known to have major consequences for individuals and the population as a whole. In New Zealand, there is a high incidence of middle ear infections among children at this time of their lives. This is particularly serious for those children who suffer persistent middle ear infections for long periods, for this can result in hearing loss.

Noise presents major issues for all children in their learning environment at school, but this is particularly pertinent for the very young at the time when language and speech are under major development. Noise was found to cause a range of effects such as impairing communication with teachers and other children, irritability, impairing learning, loss of concentration, creating behavioural issues and over stimulation. In noisy situations some respondents indicated that where children cannot effectively communicate they can resort to physical means such as to snatch or grab something rather than ask for it. It is recognised in literature that noise has the greatest adverse impact on children with hearing impairment and a range of disorders involving speech, communication, auditory processing and developmental delay. It is therefore most surprising that noise in early education has received so little attention in literature, with very few studies to date reported. Despite the worldwide trend to place special needs children in mainstream education, very little has been reported on the adverse affects of noise on these at-risk children and how it affects their learning capacity and well being in their early education settings.

13.2 Research questions

Five research questions were proposed:

1. The sound environment

What are the typical noise levels encountered in a range of early childhood centres and by how much do they exceed the levels proposed by the World Health Organization for unoccupied classrooms?

2 Personal exposure

What are the likely personal sound exposure levels of the children and their teachers and how do these relate to the New Zealand and international occupational noise criteria?

3 Observed effects on children

How does noise affect the learning outcomes and well-being of special needs children mainstreamed in early education?

4 The physical learning environment

What is the general acoustical quality of early childhood centre learning spaces and do they comply with the recommended criteria for classrooms and learning spaces given in the current Australian/New Zealand Standard?

5 Strategies to mitigate noise levels

What strategies can be developed not only in classroom design, but also in legislation and teaching practice, to ensure that children and their teachers are not placed in a situation where there is a risk of hearing loss and where there are barriers to learning for special needs children?

13.3 The sound environment

To gain an understanding of the sound environment in which children are present for long periods in their daily lives, this work firstly explored the typical noise levels in the following 2 legal categories:

- *Sessional* centres – short stay centres such as kindergartens where children attend sessions from 2 to 3½ hours per day.
- *All day* centres (where children attend more than 4 hours per day)

Research question 1 was addressed with the establishment of typical sound levels, which did seem to correlate well with the limited data available. A-frequency weighted time-average levels were recorded well above the recommended time-average level of 35 dB recommended by the World Health Organization for unoccupied classrooms and learning spaces. Sound pressure levels recorded in the centre of the learning spaces ranged from A-frequency weighted time-average levels from 65 to79 dB for the duration of individual sessions (for *sessional* centres) and the full day (for *all day* centres). In situations where the time-average levels were in the range of 75-79 dB it would be nearly impossible to gain the ideal signal-to-noise ratio of 15 dB above the background noise level even if the teacher was shouting.

13.4 Personal exposure

In assessing Research question 2 to determine the likely personal exposures of children, no other comparable data was available to give any indication of likely levels. Personal sound exposure levels varied greatly but it was never expected that personal dose levels recorded by children could well exceed the occupational noise criteria of the health and safety in employment legislation. Likewise it was surprising to record personal exposure of some staff participants to be in excess of that permitted by the legislation. Eighteen percent of children monitored in *sessional* centres and 43% in *all day* centres recorded daily sound exposure levels in excess of the maximum 100% permitted in the (adult) workplace. In addition, most of the children monitored (86% in *sessional* centres and 90% in *all day* centres) recorded peak levels in excess of 140dB on at least one occasion. Such levels of noise are deemed to be harmful to adults and it is reasonable to expect greater levels of harm to young sensitive ears. Of the teaching staff monitored, 3% of staff (*sessional* centres) and 11% (*all day* centres) recorded daily sound exposure levels in excess of 100%. Thirty nine percent of staff in *sessional* centres and 48% of staff in *all day* centres recorded peak levels of at least one exceedance over 140 dB. The earlier series of doseBadges were unable to give more specific information on the peak level exceedances.

Whenever possible, children were monitored for special events and activities they participated in both inside and outside the centre. This included music sessions, and walking excursions in the Wellington Central Business District.

Music sessions varied greatly, but there were a few which were excessively loud. One session recorded an A-frequency weighted time-average level of 93 dB for the duration of the 30-minute session, a level potentially dangerous to the hearing of young children. Quite apart from the volume of the recorded music used, expert opinion from a music specialist suggested that percussion instruments should be made from alternative materials to give the desired musical effect without the sharp impact type sound. She also recommended the holding of music sessions with small groups of children, to give increased benefit from not producing so much noise and to allow the teacher to focus more closely on the quality of music.

High levels of noise were recorded as children went out on a walking excursion around the busy inner city streets ($L_{\mathrm{Aeq\ 1\ hr}}$ = 84-86 dB) and around major road works (L_{Aeq} = 88-92 dB) when the children were walking along a temporary footpath right next to the works. The benefits of the learning experience of taking children out on excursions are not questioned, however the noise exposure is something that probably hasn't been considered before. Staff should where possible avoid taking children along the busiest routes and avoid areas, which are noticeably noisy, such as large construction works.

At the request of some participating early childhood centres, the study was extended to include some simple hearing tests on staff. Audiograms were taken of teaching staff at the beginning and the end of the working day to assess any temporary threshold shifts as a result of noise exposure. Their daily sound exposures were measured by fitting doseBadges to the staff members who participated, to see if there was any identifiable link between the threshold shifts and the noise exposures. Unfortunately in the testing conditions, noise levels from heavy rain and the background noise on the premises, made accurate testing extremely difficult. While some audiograms showed small movements in hearing threshold levels, these were not enough to be considered significant as they fell within the margin of error.

The audiograms also indicated the current hearing status of each participant. Younger staff in the 20-25 age group generally did not show any signs of damage, but the characteristic notch was beginning to show in staff members in their mid 30s suggesting the emergence of noise-induced hearing loss. More evidence emerged in staff members in the 40-45 age group and moderate to severe loss was detected in a staff member in the 60 - 65 age group. It is unlikely that presbyacusis would be the sole cause of severe hearing loss in this age group but would certainly augment hearing loss induced by excessive noise exposure or due to a medical condition. Up until now, this has been given little or no attention by the regulatory agency, the New Zealand Department of Labour. While the health and safety of teachers in their workplace is generally covered by the New Zealand *Health and Safety in Employment Act 1992* and the New Zealand *Health and Safety in Employment Regulations 1995*, it is doubtful if this legislation can successfully be applied to addressing noise as a hazard to teachers in the workplace without the development of a comprehensive code of practice and amendment of the legislation to cover such issues. If strategies proposed by the *Health and Safety in Employment Act 1992 (Clauses 8-10) for* the management of hazards were implemented, children (the source of noise) would need to be isolated from their teachers, or the teachers required to wear hearing protectors.

If the findings of this limited study are representative of the hearing status of staff in the early education sector, a considerable number will have significant levels of hearing loss by the time they retire. Urgent investigations are now needed to assess the levels of hearing loss in this sector group of workers along with the levels of hearing loss directly attributable to noise exposure at work.

13.5 Observed effects of noise on children

Children known or suspected to be adversely affected by noise were identified from literature and advice from specialists who work with these children. In addressing Research question 3, information was sought on how noise affects children in general, as well a range of children with identifiable needs.

The respondents consisted of teachers, special education professionals and some parents. They reported a wide range of adverse effects of noise in general on the children's well-being and educational outcomes. They identified effects such as impairing communication between the children themselves and their teachers, irritability, impairing learning ability, loss of concentration, creating behavioural problems and over stimulation. Information was sought from children experiencing conditions such as developmental delay, Down syndrome, attention-deficit/hyperactivity disorder (ADHD), autistic spectrum disorder, auditory processing disorders and giftedness. Many of these children were often startled or distressed by loud sudden and unexpected noises. Respondents identified the most adverse outcomes for children on the autistic spectrum as the majority of these children along with a subset of gifted children experience a condition known as sensory integration disorder. These children often have extreme sensitivities to certain types of noise, which can vary considerably from one individual to the other. It appeared that primary adversary affects included high levels of distress, aggravation and behavioural issues self stimulating behaviours such as hand flapping or rocking, hands over their ears, screaming or groaning to try and block out the sound and even a trigger for vomiting, on-going abdominal pain and an epileptic or epileptiform seizure.

Secondary effects were identified as learning impairments, distraction from tasks and compromise communication. As those experiencing classical autism already have serious problems with speech and communication, noise only exacerbates the problems they already have.

Respondents identified space as a critical issue for special needs children mainstreamed in early childhood centres. The lack of quiet spaces to conduct one - on-one speech language therapy and work with these children was strongly criticised as well as these children having no quiet places to escape the din. The staff room is often used for one-on-one work and in one case, the toilet lobby had to be used as no other space was available. This is not inclusive education and an unsatisfactory situation in properly meeting the educational and welfare needs of these children. It appears that when the policy drive was introduced to place special needs children in mainstream early education environments, little or no consideration was given to a conducive and an acoustically appropriate learning environment for these children.

The study was not designed to formally assess measured learning outcomes as a result of noise. This was beyond the scope of this work and outside the strict ethical approvals given. However a number of hypotheses and questions can be proposed as a result of this work on the effects of noise on the educational outcomes of children with identifiable needs. In addition, the impact of not being able to provide specialised or individualised education in ideal educational settings is worthy of further investigation. These hypotheses and questions need to be formally investigated and tested.

Excessively loud fire alarms were identified by a number of respondents as being so loud that they caused young children distress and may compromise a safe and orderly evacuation in a genuine emergency. On examination of the relevant standard, there appears to be widespread misinterpretation, as alternative non-audible alarms systems are permitted when audible devices could cause distress to occupants in settings such as early childhood centres.

From the responses given, it appears that of all groups of children with identified needs, those on the autistic spectrum may be the most adversely affected by noise of any group. It is surprising that the problems of this group have been largely overlooked in literature on classroom noise, which tends to focus on the hearing impaired. While clinically based references and literature on autism clearly identifies the issues of overwhelming sensitivities to noise and other senses, other studies on noise in education to date have largely failed to identify the seriousness of noise to this group. It is critical that the adverse affects of noise to this highly at-risk group be identified so that their needs can be given primary consideration when strategies and remedial measures are taken.

While the respondents clearly identified noise as affecting children's behaviour and learning from their observations, it is important to point out that dedicated research is now needed to conclusively establish the effects of noise on the behaviour and learning outcomes of young children.

13.6 The physical learning environment

Many early childhood centres are in premises converted from other uses such as commercial and domestic buildings. On the whole those in residential areas are in converted homes and schoolrooms etc., while those in the central business district are in commercial premises often shared with other tenancies. In addressing Research question 4, the acoustical environment was assessed.

Few premises had acoustic treatment and in most cases reverberation times exceeded those recommended for school rooms (0.4-0.6 seconds) across the standard octave frequency bands (63-4,000 Hz). In a couple of cases, the retrofitting with acoustic wall and ceiling tiles showed a marked reduction in the reverberation times as measured before and after the retrofitting with acoustic panels. It is imperative that appropriate design criteria be available during the building, change of use or major renovation stages of such facilities, where appropriate design criteria can be appropriately planned and budgeted. It is far less desirable to try and effect a clean up after finding serious problems.

13.7 Strategies to mitigate noise levels

This work and the high levels of public interest, which were generated through the news media, appeared to substantially raise awareness among teachers and administrators in the early education sector. It was fortuitous that an overhaul of the New Zealand *Education (Early Childhood Centres) Regulations 1998* was occurring at the time of this study and giving the added incentive for developing Research question 5. In the initial consultation by the New Zealand Ministry of Education with stakeholders in the early education sector, noise emerged as a key issue, which needed addressing. In answer to a request for advice as to how noise could be regulated in accordance with current teaching practice and the current levels of resources, a discussion document was prepared for the Criterion Development Team of the New Zealand Ministry of Education, outlining legal precedents and the frameworks, which could be considered. In this document, resource implications were discussed and the relative advantages and disadvantages of each framework were presented. The Ministry of Education accepted the recommendations of the report in full adopting the *all practicable steps* framework over the *setting of prescribed standards* alternative. Clause 3:20 of the Draft criteria[*] was a direct result of this work to control noise to a measurable outcome such as the ability to conduct normal speech and communication. The latter part of the clause is a recognition of the rights of all children, especially those at-risk, to protection from the

[*] *"All practicable steps are taken to ensure that noise levels do not unduly interfere with the normal speech and/or communication, or cause any child attending distress or harm"*

adverse effects of noise. The lack of quiet spaces and excessively noisy fire alarms still remains unresolved.

13.8 Limitations of this work

There were a number of limitations with the research methods.

13.8.1 Personal sound exposure of children.

The doseBadges were designed for measuring compliance with the international workplace exposure criteria for noise (promulgated into the New Zealand health and safety in employment legislation). Due to memory limitations being a very small unit, the doseBadges have a high cut-off point where noise exposure data of less than 75 dB is discarded. This is not entirely suitable for children giving a conservative estimate of the children's exposure. A lower cut-off point at 65 dB (i.e. data of less than 65 dB is discarded) would have given a better representation of the personal exposure of the children.

13.8.2 Fixed sound level measurements

Unlike the New Zealand standards for the measurements and assessment of environmental noise or the approved code of practice for noise in the workplace, the lack of standard methods for the measurement of noise levels in educational settings remains a significant limitation. This means that it remains the choice of individuals taking the measurements, which can vary greatly and significantly affect the results obtained.

13.8.3 Responses to questionnaires

The respondents gave their observations on the effects of noise on various groups of children and educational outcomes and created. From the observations reported a number of hypotheses have emerged that need to be formally tested. There are a number of confounding factors such as severity of the condition and individual responses to noise within special groups such as those on the autistic spectrum, which would need to be addressed.

The small sample sizes were a limitation, which cannot be ignored. A difficulty with the New Zealand early childhood education sector is that it is it is diverse and that children with special needs are generally mainstreamed which is a principle of New Zealand educational policy. There are very few special early education centres dedicated to specific disorders such as autism. Some disorders cannot be effectively diagnosed until well into school age such as central auditory processing disorder and giftedness. Reliable information on these groups is sparse. Retrospective reporting by parents, whose child subsequently received a formal diagnosis outside the early education years, introduces a level of unreliability.

The issues of bias introduced by respondents having their own agenda is an issue difficult to avoid. However in all the responses received and feedback obtained, most of the responses came with good reasoning and descriptions justifying what was said. A number of respondents preferred to complete the questionnaire verbally due to time constraints and in some cases staff preferred to do it as a group where 2-3 staff completed one questionnaire. While there were obviously some positive attributes to this with staff discussing and thinking about each question, it did introduce a negative bias with less numbers counted than those actually responding.

13.8.4 Occupational hearing issues of staff

Hearing tests were carried out as a special request from three large inner city childcare centres. As the staff work long hours testing was organised immediately before work (5am to 7am) and again after work (5pm –7pm) . The staff at one centres had testing done at Massey University before and after work. During the morning testing time heavy rainfall occurred, the noise of which made the testing difficult. In addition a proper testing booth was not available. Staff at the other centres preferred to have their tests done at their place of work and again this had to be done in a noisy environment. While it would have been preferable to do all tests in quiet surroundings, the difficulty of working around rosters, and the long working hours, meant that repeat testing in ideal test conditions was not possible. In addition, the resources were not available to establish any control groups.

13.9 Recommendations for future study

This study has lead to the following recommendations for future work:

1. A comprehensive study be undertaken to identify all the at risk groups of children adversely affected by noise in early childhood centres and clearly establish the effects of noise on the learning outcomes of these children.

2. A standard method or code of practice be established for measurements of sound pressure levels in learning spaces which will allow valid comparisons between studies using the same standard methods.

3. A study be carried out to examine the personal sound exposure of young children over the full 24 hours, which would include typical exposures at home and activities outside formal education settings.

4. A comprehensive study be undertaken of the personal sound exposures and the hearing status of teachers and contact staff. It may also be necessary to examine how the existing code of practice for management of noise in the workplace could be modified to include this group of workers.

5. An on-going study be established to monitor and detail any acoustic treatment as it occurs in childcare centres as it occurs so any improvements can be assessed and documented.

14 Appendices

14.1 Human Ethics Committee approval

As the project involved the direct participation of young preschool children, full Massey University Human Ethics Committee approval was required. Approvals were given (Wellington 03/120 and 05/34). The special conditions required of the committee were met in full:

- The doseBadges were intrinsically safe and did not emit any kind of radiation (like a mobile phone) or signal while they were in operation.

- A doseBadge would not be fitted to a child under 3 years old. They were considered not suitable for babies or crawling children as falling on the badge could hurt them. Badges would not be fitted to any children if likely to cause distress or anxiety such as those on the autistic spectrum.

- Full parental written consent of parents was required. A letter / information sheet was addressed to every parent explaining the project. Children were selected by the teachers to wear a badge and a letter was sent to each parent explaining this part of the project in full and a consent form to sign. (Copies attached)

- No child would be required to wear a doseBadge even if parental consent was obtained. They would be removed on request of the child.

- Researchers had to wear a name badge, be under full supervision of teaching staff at all times, and if possible in their line of sight.

A variation was sought on the above approvals to carry out pure tone audiometry on teachers and staff members who had contact with children.

All personal details of the participants, and the names of the early childhood centres, which participated in this study, were kept strictly confidential and not disclosed in this work nor in any other report.

The Massey University Human Ethics Committee approved a number of model letters, information sheets and consent forms to be issued to the participants (i.e. governing bodies, parents, teachers etc). Two of these documents have been included below as examples.

Massey University
COLLEGE OF SCIENCES

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AND HUMAN HEALTH
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Kai-oranga-ā-tāngata
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Date

Dear

COMPREHENSIVE STUDY: EFFECTS OF NOISE ON CHILDREN AND TEACHING STAFF IN EARLY EDUCATION

Thank you again for your invaluable assistance with our preliminary study on noise levels in early education. There has been tremendous interest in the study both nationally and internationally. We are now planning a major project to investigate the types and levels of sound generated in early childhood facilities. This will be the first ever comprehensive study of its kind in the World following concern raised by the World Health Organization to the International Institute of Noise Control Engineering.

The project will involve three stages:

1. Physical examination and acoustical qualities of buildings

Examination of the building's construction and environment (brick – light frame timber etc and the types of internal surfaces. The inspection will also include acoustical analysis such as reverberation times. These will be done at times children are not present (unoccupied)

2. Personal noise dose exposure

The research would involve the fitting of a small noise dose badge to a staff member or to individual children 3 years and over with appropriate consent. This is attached to the clothing by a safety pin (rather like any other badge). At the end of the sampling period, it is removed and the information is downloaded sometime later. We have examined the carefully the specifications of the equipment and can guarantee that the equipment is intrinsically safe by international standard and does not emit any kind of sound, static electricity or transmit any kind of microwaves (such as cell phones, radio waves) or anything harmful whatsoever. This is a requirement or the international standard under which the equipment is manufactured and tested
The badge is small and light enough (50grams) not to cause any discomfort to children. However if a child didn't wish to wear it wouldn't be fitted. We enclose information

sheets on the dose badge, which will also be available to any staff members or parents for inspection.

3 Interview of staff on the effects that noise has on the children

The interview would involve one staff member from each centre on a strictly voluntary basis. Time involved would be about 15 –20 minutes.

Covering letters with detailed information and consent forms for data collection involving staff and children are enclosed.

Every attempt to ensure confidentiality is given and individuals and centres will not be identified by the research team to any third party or in any report or publication. We have developed a unique coding system, which was trialed very successfully in our earlier study. This will be extended to cover individual participants as well as centres. It is a requirement that all confidential information will be kept in secure storage with restricted access. In accordance your requirements and individual managers, all parents whose children are present during the times research is carried out will be notified. Draft letters information sheets and consent forms are enclosed.

The equipment used is robust but in the event or loss of damage the Centres or any individual will not be held in any way liable for what ever reason. This remains the sole responsibility of Massey University and its insurers. However in the interests of all concerned the researchers must remain on the premises at all times the equipment is in operation so as to respond to any requests of the staff.

I would value the opportunity to meet and discuss the project with you in person if this is possible at a time convenient to yourself. In this way we can discuss any immediate concerns and questions you have. ☎ (04) 801 2794 x6705.

The researchers agree to:

- Maintain strict confidentiality by not identifying the Centre to any third party or in any report or publication.
- Comply with all instructions of the teaching staff or management and not to interfere with any staff in the course or their duties or the children in the learning and enjoyment of the facility.
- To keep the manager fully informed of all results pertaining to this facility
- Allow the manager to view and comment on any manuscripts prior to publication
- To consult the manager and governing body before any press releases are made due to the anticipated high level of interest

The Massey University Human Ethics Committee require the following participants' rights as part of the approval process:

- As the governing body you have the right to decline to participate or withdraw any of your centres from the study at any time up to 30 November 2003.

- Provide information only on the strict understanding that your centres or participant staff and children will not be named or identified in any way (unless expressed permission is given to the researcher).
- Be given access to a summary of the project findings at the conclusion.

This project has been reviewed and approved by the Massey University Human Ethics Committee, WGTN Protocol 03/120. If you have any concerns about the conduct of this research, please contact Mr Jerry Hubbard, Acting Chair, Massey University Campus Human Ethics Committee: Wellington, telephone 04 801 2794 X6583, email J.J.Hubbard@massey.ac.nz .

Yours sincerely,

Stuart J McLaren
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EFFECTS OF NOISE ON CHILDREN AND TEACHING STAFF IN EARLY EDUCATION

CONSENT FORM
(Governing bodies)

THIS CONSENT FORM WILL BE HELD FOR A PERIOD OF FIVE (5) YEARS

I have read the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I agree to participate in this study under the conditions set out in the attached letter.

Signature: .... **Date:** ....

Full Name - printed ....

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Notice : To All Parents and Staff

MASSEY UNIVERSITY STUDY – EFFECTS OF NOISE ON CHILDREN AND TEACHING STAFF IN EARLY EDUCATION

On [date], Stuart McLaren from Massey University will be conducting a research project in our centre as part of his PhD studies. The centre has been randomly selected as part of a study on noise and acoustics in early childhood learning rooms. This has originated from concerns worldwide raised by the International Institute of Noise Control Engineering (I-INCE) on the advice of the World Health Organization. INCE has established an international working party, which includes New Zealand, to evaluate noise and reverberation control for learning spaces.

Some children have been randomly selected to wear little noise doseBadges as part of the study and their parents have already given consent. As these look like little space ships the staff feel many children may want to wear them. We do have a good supply of dummy badges so that other children need not feel they have been left out. The researchers will be wearing identity name badges and be discreetly taking noise measurements and relating these to the activities carried. The researchers are not permitted to interfere with the normal operation of the centre.

Thank you for your cooperation in this important study. If you have any further questions or concerns, please relate these with the Centre manager/Head teacher of the centre who can directly refer these to the researchers. You are also welcome to contact me directly for more information. I can be contacted by telephone 801 2794 extension 6705 or email s.j.mclaren@massey.ac.nz.

Stuart J McLaren
Senior Lecturer in Health Science
Massey University in Wellington

14.2 Development of a noise management plan

With the adoption of the *all practicable steps* model in the new draft legislation, an effective tool to meet the requirements of the criteria on noise is to develop a noise management plan as part of the policies and procedures of an early childhood centre. A noise management plan is used by a variety of noise generating industries to identify noise issues and then formulate a plan to mitigate or control these. A plan should be a living document, which is regularly review and consulted. It could be submitted as part of documentation for the Education Review Office evaluations of early childhood centres. In addition prolonged exposure to noise may also be an occupational issue for many staff.

To assist the development of this strategy a guide to preparing a noise management plan has been developed as a point of reference for centres wishing to adopt this initiative with a model plan. While there is no single method or format to prepare a plan, the following guide and model development plan serves as a tool for discussion, further development and adoption.

Essential elements of a noise management plan

The essential elements of a noise management plan can be broadly divided into 5 parts. The most important aspects of any plan are the legal and policy directives. Policy statements could be developed under the following themes.

Part 1- Policy statements

1 A description of the legal requirements pertaining to noise and commitment to staff knowledge and implementation.

2 A living document that is regularly used and reviewed. A commitment to on going review and amendments to the plan needs to be made.

3 The philosophy that the centre will adopt in managing noise. For example:

Educational and other beneficial activities which generate noise will not be suspended or curtailed, but will be carried out to deliver maximum benefit along with a commitment to manage noise levels as much a possible.

Mitigation of unnecessary noise, which can be curtailed. For example: lubrication of squeaky equipment, solutions to minimise noise from actions such as doors banging, furniture scrape etc.

Noise producing toys will be chosen carefully using those that are quiet but still provide the children with the same benefits

4 Inclusion and protection of at-risk special needs children.

5 Noise-induced hearing loss as an occupational issue for teaching and other contact staff.

Part 2 Noise issues in general

1 A summary of the types of noise generally found in early childhood centres. along with any noise specific to a particular centre

2 Noise issues for the most at-risk children.

3 Occupational exposure.

Part 3 Strategies and practice

1 A statement of recognition that play is an important part of a child's learning and development, which generates noise can be included. A commitment to strive to achieve a balance over what noise is a consequence of play and learning and what is excessive and detrimental. Teaching strategies may be introduced here such as the use of quiet voices inside and any technique for teaching attentiveness etc.

2 Any noticeable noisy times such as transition times from on activity to another can be included and how this is to be managed.

3 Sessions generating noise by their nature should be addressed. Music sessions such as the use of recorded music will be played to the volume for children to experience, learn from and enjoy the music, but not of a volume to cause distress or hearing loss. Other strategies could include the choice and type of percussion instruments (made of plastic or flax rather than hard wood to reduce the sharp piercing impact sound) and to teach the children to play musically and not to bash the instruments for the purpose of making noise.

4 Specific noise issues such as furniture scrape, squeaky equipment noisy toys can all be addressed. Simple strategies such as making sure caps are fitted to furniture to minimise scrape, lubrication of swings etc, and the use of ride on toys with rubber wheels rather than hard hollow plastic wheels can be outlined.

5 Avoidance of the Lombard effect where teachers addressing a noisy group will naturally raise their voices to be heard over the din. What other more positive strategies can be used rather than shouting at the children?

6 Any other innovative ideas adopted by the centre to minimise noise. For example: a traffic light system for noise and ear muffs on the carpentry bench (both developed by a local kindergarten).

7 As inclement weather often confines children indoors, the strategies for managing children could be outlined here.

8 A plan for special needs children and/or those with high levels of sensitivity to noise. How will these children be managed?

Part 3 Noise attenuation through the building structure

In many centres this is an issue with excessive reverberation. The centre could identify any long terms goals to improve the acoustic environment. This could include DIY solutions such as the fitting of self-adhesive ceiling tiles of soft board wall panels as well as professional consulting services engaged.

Part 4   Externally generated noise intruding into the centre

Noise outside the control of the centre can be an issue and this may involve seeking assistance from a law enforcement agency such as the city or district council's environmental health officer/noise control officer. Contact details should be included if needed. Many council staff treat early childhood centres like any other commercial activity and would not necessarily know or give due consideration to the presence of at risk children when considering such activities as noisy construction works which are granted consent by the council in the resource consents process. It is reasonable for the centre to act as advocates for their children and not to assume council officers are well informed of the issues that the centre face and the presence of special needs children who are adversely affected by noise. The centre could formally ask council to ensure that they notified of any noisy activities in the vicinity of the centre and to be given due consideration in the approval process. A model letter is enclosed.

Part 5   Education

The education of children at an early age is the core business of the early childhood education centre and education about loud noise and hearing damage should be included. The earmuffs on a carpentry bench is an excellent educational initiative. The centre could indicate education initiatives to parents perhaps with key messages in notices to parents or by setting the example. Education can also extend to the relevant law enforcement agencies such as city/district council staff who would not normally be aware of the issues of externally generated noise for the children, especially those most at risk.

Part 6   Occupational exposure

Staff exposed to occupational noise over a working life are at-risk of hearing loss especially in the retirement years where the natural loss of hearing with age (presbyacusis) becomes more significant. Implementation of a strategy to alert staff to the possibility of hearing damage and to provide information with a means for early detection should be included. All hearing associations have hearing therapists or hearing advisors who can conduct pure tone audiometry tests and provide counselling for free or nominal fees. They will also refer clients to public or privately based audiology or audiometry services if necessary. Information and contact details of theses local services should be included in the plan.

A model noise management plan.

Policy 1

The centre staff are required to be familiar with the legal requirements regarding noise and will ensure that these requirements are met at all times. All permanent staff to the centre will be informed of this plan and be required to meet these requirements as part of their duties.

Policy 2

The noise management plan will be evaluated internally at staff meetings and internal audits. This plan will be evaluated at least once a year and necessary amendments made.

Policy 3

The centre will not to cancel or prohibit any beneficial activities which by their nature generate noise/sound but will strive to conduct these activities in a manner that gives the children the full educational benefit and at the same time consciously manage noise levels as much as possible.

Policy 4

The centre will identify, eliminate or control as much as possible any unnecessary noise (such as squeaky equipment) by regular lubrication and /or other maintenance. Staff will not generate unnecessary noise such as loud background music.

Policy 5

The centre will not permit toys that have the potential to cause hearing damage. Noise from such toys will be evaluated along with other hazards before any such toys are permitted in the centre.

Policy 6

Staff will identify and monitor special needs children known to be adversely affected by noise. Intervention will be put in place for any known noisy activity to manage these children as much as possible. This will include strategies to move them to a quieter area of the centre or manage the level of noise before they become distressed.

Policy 7

The centre has a commitment to the aural and other occupational health effects of work. Staff are encouraged to have their hearing tested by approved providers especially if conditions such as tinnitus or other such warning signs are experienced. We encourage and assist staff to put strategies in place to protect their hearing both inside and outside of work.

Legislative requirements

- Clause 2:16 of the *Criteria for the Licensing or Certification of ECE services* requires that parts of the building used by children have acoustic absorption materials necessary to reduce noise levels that may negatively affect children's well being.

  Clause 3:20 of the *Criteria for Licensing or Certification of ECE services* requires that *all practicable steps* are taken to ensure that noise levels do not unduly interfere with speech and /or communication or cause any children attending distress or harm.

General types of noise sources and issues found in early childhood centres

- Noise transmitted through or reflected by the building structure
- Noise generated as part of the centre activities
  - Noise from children themselves (while engaged in play, when distressed etc.)
  - Noise from the use of equipment, fittings, toys, hi-fi, musical instruments etc.
  - Noise intrusion from activities outside the centre (over which the centre often have little or no control)

- Protection of special needs children who are mainstreamed in early childhood centres and known to be adversely affected by noise. This includes children with middle ear infections, hearing impairment, auditory processing disabilities and sensory integration disorder.
- Excessively loud fire alarms.
- Occupational noise exposure

Identification of Specific issues

Noise generated by children during play

Play is an integral part of the learning and development of the child and there will always be noise generated by children. The staff will strive to always achieve a balance over what is necessary for the children in their learning and enjoyment and what is excessive to the detriment of children and their teachers. Teachers and staff will monitor noise to ensure as far a possible it doesn't have any adverse effects such as causing degradation of speech and communication. Children will be reminded to use their quiet voices inside. Listening and attentive skills will be taught at mat time with a variety of games and activities requiring these attributes.

Immediate attention is given to children who are distressed or involved in any unacceptable noisy activity such as fighting, inappropriate language etc.

Noise generated by children in transition from one activity to another

This is often a noisy time. The staff will focus gaining the children's cooperation to get these tasks done as speedily as possible. Music has been successfully used to motivate children and set the scene and we will adopt such initiatives.

Sound generated during music sessions.

Music will be used for specific purposes such as to create a calming atmosphere. Music lessons will be conducted with the view to teach musicality but not of a volume to cause distress or harm to the children. Children will be taught and encouraged to play instruments musically and not to bash them for the purpose of making noise. Claves and other percussion instruments will be made of plastic or flax so as to give the musical benefit without generating sharp, piecing and impact-type sound. Drumming and rhythm are specifically taught.

Noise generated by furniture scrape and fixtures

Scraping of furniture can be a disturbing and annoying. All rubber caps on furniture will be regularly checked for wear and caps replaced as needed to minimise scrape. Any wooden self-closing doors to the kitchen will be fitted with simple rubber mounts to stop them constantly banging.

Toys and playground equipment

Toys and equipment, which make unnecessary noise, are not acceptable. Bikes and similar ride-on toys with hard hollow plastic wheels, which are excessively noisy, are being progressively replaced with quality rubber tyred toys. Other noisy toys such as toy cellphones, clackers etc are not permitted. Swings and other such moving equipment are regularly monitored for squeaks etc and will be lubricated regularly. Grease and oil are available in the centre for this purpose

Lombard effect

Teachers will endeavour to not raise voices over the top of children (known as the Lombard effect) but will seek other more positive ways to gain the children's attention and /or cooperation to quieten down. We have adopted a red flashing light which is turned on as a signal to alert children to the noise level and to gain their cooperation.

Carpentry bench

Policy 3 requires that such activities are not curtailed on account of noise. Earmuffs are provided on the carpentry bench and children encouraged to wear them. We have also carpeted the surface of the bench to reduce noise. We encourage hearing conservation in all activities we engage the children in. Children are strongly encouraged to use the earmuffs provided on the carpentry bench as would happen in industry.

Inclement weather

Inclement weather confines children indoors and it is necessary to be well prepared with a range of engaging activities such as painting, puzzles, play dough or creative play such as building blocks. Children will be actively encouraged to participate in the range of activities provided and tasks given to maintain interest. Music sessions and other indoor activities will be fully utilised on that day. Children will be reminded to use their quiet voices on such days and to keep the noise down. We strategically use calming music to create a serene atmosphere.

We are endeavouring to increase the available space during wet weather by the addition of a covered play area. This is the policy of our governing body for all their centres.

Special needs children

This centre usually has some special need children enrolled. In the case of those known to be effected such as the hearing impaired, or those on the autistic spectrum, the teachers and education support workers assigned to the child will monitor the noise levels and the child to ensure that any sign of the child becoming distressed that action is taken to remove the child to a quieter corner. We do not have a separate quiet space. It is a long term goal, which is subject to a successful grant, to create a quiet reading room or area in which one - on - one work with our special needs children can be undertaken by the speech language therapists and other professionals from Group Special Education or similar providers of early intervention services. In the meantime headphones are provided with quiet music of his/her choice to wear as a calming strategy. The staff office is presently used.

Noise attenuated through the building structure

There is no acoustic treatment in the centre. Due to limited resources we are unable to seek professional advice to improve the acoustic environment (i.e. reduce reverberation times). However we propose to undertake the following as resources become available.

- The fitting of self-adhesive perforated ceiling tiles which we will undertake with the assistance of parents.

- The fitting of hessian covered soft wallboard panels through out the centre. We are advised that with a combination of the above will greatly improve acoustics

- The provision of carpet mats over areas of the floor not likely to become soiled or wet.

Noise generated outside the centre but causes a nuisance and obstructs the learning and well being of the children.

Noisy neighbours with loud stereos and the testing of engines trouble the centre from time to time. The staff will raise the matter with the Council's environmental health officer/noise control officer to seek intervention when the noise is persistent loud, disturbing and causing a nuisance to the centre. The officer's details are given:

Environmental Health Officer
Xxxx City Council
Tel xxx

Participation in consent process for activities, which will adversely impact on out children

The centre wishes for the council to be aware of the presence of the centre and the effects of noise especially on our vulnerable children, when they approve any application, which will increase the ambient noise level to our centre. A letter has been sent to council advising them to ensure that all noise activities which will impact on the children and the centre are given due consideration in planning. We wish to be notified of all such activities likely to impact on our children in the planning stages and be allowed to make submissions in the consents process.

Child Education

We will include hearing protection and looking after our hearing in our education to children. The earmuffs provided on the carpentry bench are a good education initiative.

Parent Education.

Many children are subjected to excessive noise at their homes. We consider our role to set the example and to educate parents on matters, which directly affect their children. Through notices to parents we will issue key messages on hearing conservation in children.

Potential occupational. hearing loss of staff

Noise can be a serious occupational hazard especially over a prolonged working life. As being an *all day* centre, our staff work long hours, so length of exposure as well as the levels of noise are a concern. To minimise this we have a range of contact and non-contact periods and duties. Information sessions and material for staff will be provided to ensure that they are aware of the issues surrounding their own aural health and this centre strongly supports hearing protection and preservation. We encourage staff to take advantage of the services below and will arrange for any staff member wishing for a hearing test to be referred.

In this area, hearing tests are available from 2 providers:

List details here

Part 4 Letter to the City Council

The Chief Executive Officer
Xxxx City Council

Dear Sir/Madam

***Resource Management Act 1991*:Noise producing activities**

We are a childcare centre containing X children some of which are special needs children with extreme sensitivities to noise. We have Y of these children mainstreamed in our centre with targeted support according to their need.

New legislation now requires childcare centres to take all practicable steps to protect our children from distress or harm caused by noise and this includes noise generated outside our centres. Impact noise from large construction works such as jack hammering and pile driving can be extremely distressing to these children. Children with special needs especially those with hearing impairment or auditory disorders such as autism are particularly at-risk to the adverse affects of such noise. It is their fundamental human right to be fully included in education and not be subjected to what is essentially cruel and inhumane stimulus for them. If there are to be one-off noisy activities, we would like to be consulted well in advance as there may be visits or alternative activities we could organise to take the children away from the premises.

We request that large works likely to impact on our centre be approved via the notified consents process and we be informed of such proposed activities so that we can make appropriate representation. We would like council officers to realise the difficulties that our children face and to consider their needs when approving such activities. We will also be happy for any council officers or applicants to consult us in the planning stages.

Yours sincerely

Director

14.3 Peer reviewed journal articles directly attributed to this work

1 McLaren, S., Dickinson, P, *Noise in early childhood centres and effects on the children and their teachers.* Early Childhood Folio, 2003. **7**.

2 McLaren, S., *Noise and at-risk children in early childhood education centres.* Early Childhood Folio, 2005. **9**: p. 39-43.

3 McLaren, S., Dickinson, P, *Noise in early childhood centres and how safe is the level of noise.* New Zealand Research in Early Childhood Education, 2005. **8**: p. 71-79.

4 McLaren, S., *Noise provisions and at-risk children in New Zealand early childhood centres.* Environmental Health, 2007. **7**(1): p. 60-70.

Full papers included (~.pdf format) in CD Rom in the rear cover pocket.
(File format ~ Journal Article1.pdf)

14.4 Conference papers directly attributed to this work

1 McLaren, S., Dickinson, P.,. *Noise in early educational facilities and impacts on the children and teaching staff.* in *Internoise 2002, The 2002 International Congress and Exposition on Noise Control Engineering.* 2002. Dearborn, MI, USA.: International Institute of Noise Control Engineering.

2 McLaren, S., Dickinson, P,. *Noise in early childhood centres and its effects on staff and children*. in *Internoise 2004, The 33rd International Congress and Exposition on Noise Control Engineering*. 2004. Prague: The International Institute of Noise Control Engineering.

3 McLaren, S., and Dickinson, P.,. *Children's sound exposure*. in *Internoise, 2005, The 34th International Congress and Exposition on Noise Control Engineering.* 2005. Rio de Janeiro: International Institute of Noise Control Engineering.

4 McLaren, S., Rickson, D, Jones, L., Dickinson, P., *Noise provisions in New Zealand early childhood education centres and a comparison of sound pressure levels with perceived noise assessed by trained observers*. in *Internoise 2006. The 35th International Congress and Exposition on Noise Control Engineering.* The International Institute of Noise Control Enginnering.

5 McLaren, S. *Noise in early education. A special problem for autistic children*. in *A different way of thinking. Conference of Autism New Zealand Inc.* 2006. Wellington: Autism New Zealand Inc.

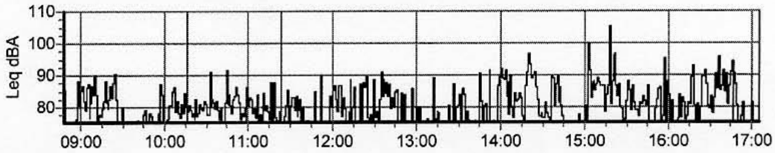
Full papers included (~.pdf format) in CD Rom in the rear cover pocket.
(File format ~ Conf. Paper1.pdf)

14.5 Sample doseBadge monitoring report

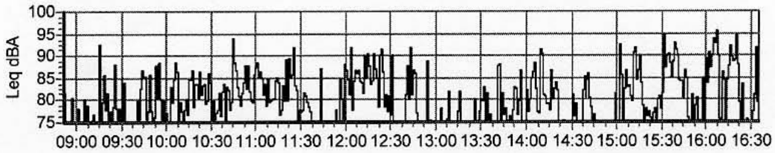
Noise Dosimetry Report

Listing all measurements.

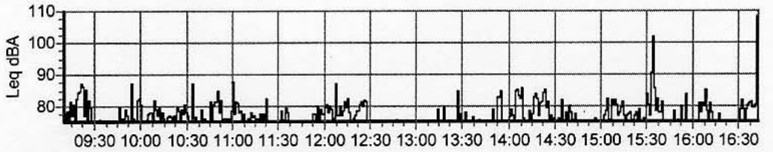
doseBadge	0451
Dose %	104
Exposure Pa2h	1
Leq dBA	85.2
Meas.Time	15:12 5/03/0200
Peak	exceeded
Peak Level dBC	140
Child's name	



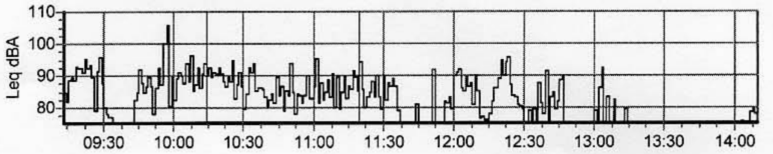
doseBadge	0452
Dose %	70
Exposure Pa2h	0.7
Leq dBA	83.7
Meas.Time	15:08 5/03/0200
Peak	exceeded
Peak Level dBC	140
Child's name	



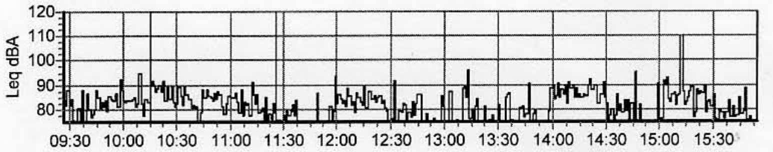
doseBadge	0453
Dose %	73
Exposure Pa2h	0.7
Leq dBA	84
Meas.Time	14:50 5/03/0200
Peak	exceeded
Peak Level dBC	140
Child's name	



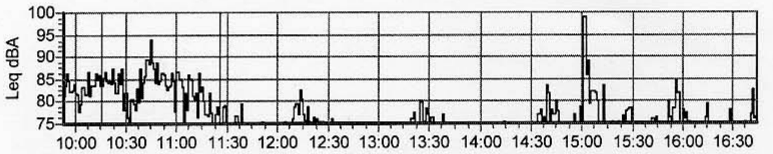
doseBadge	0454
Dose %	120
Exposure Pa2h	1.2
Leq dBA	88.1
Meas.Time	14:47 5/03/0200
Peak	exceeded
Peak Level dBC	140
Child's name	



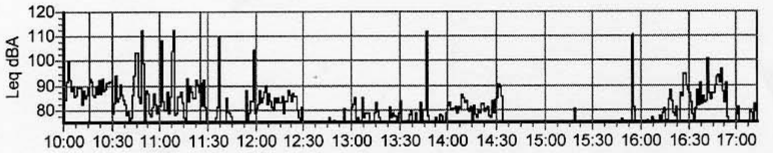
doseBadge	0450
Dose %	140
Exposure Pa2h	1.4
Leq dBA	87.5
Meas.Time	14:33 5/03/0200
Peak	exceeded
Peak Level dBC	140
Child's name	



doseBadge	2301
Dose %	27
Exposure Pa2h	0.2
Leq dBA	80.1
Meas.Time	14:07 5/03/0200
Peak	exceeded
Peak Level dBC	140
Teacher's name	

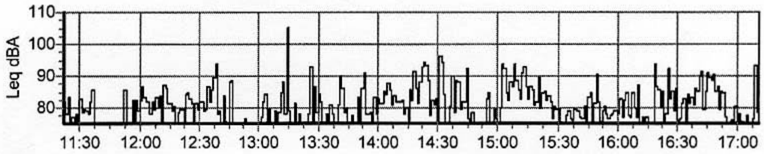


doseBadge	2303
Dose %	633
Exposure Pa2h	6.4
Leq dBA	93.5
Meas.Time	10:00 4/03/2020
Peak	exceeded
Peak Level dBC	140
Child's name	

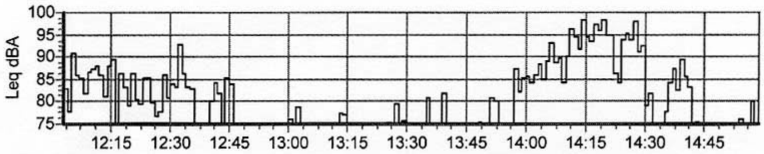


Noise Dosimetry Report

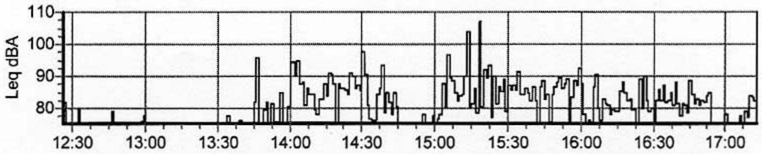
doseBadge	2304
Dose %	79
Exposure Pa2h	0.8
Leq dBA	85.5
Meas. Time	11:22 4/03/2020
Peak	exceeded
Peak Level dBC	140
Child's name	



doseBadge	2302
Dose %	56
Exposure Pa2h	0.5
Leq dBA	87
Meas. Time	12:03 4/03/2020
Peak	exceeded
Peak Level dBC	140
Child's name	



doseBadge	2305
Dose %	102
Exposure Pa2h	1
Leq dBA	87.5
Meas. Time	12:26 4/03/2020
Peak	exceeded
Peak Level dBC	140
Child's name	



10 measurement(s)

database file: Preschool

14.6 Survey and questionnaire forms

1 Interview questionnaire form
2 Building and environment survey form

Interview-questionnaire

Acoustics and characteristics of noise in Early Education

Interview Number ________________

Date__________________

Centre Code ___________________

Staff Code_____________________

This Interviewer's Question sheet (not shown to the interviewee). The interviewee will also be given the list of the identical questions *but the text below in italics will not be included.*

Teaching spaces

1. What do you consider the aspects of your teaching spaces to be the most important? Can you rank those given with 1 being the most important to 5 the least important

   - ☐ Lighting
   - ☐ Ventilation
   - ☐ Acoustics (listening environment)
   - ☐ Equipment
   - ☐ Adequate space

2. How do you experience the listening environment in the rooms you teach in?

   - ☐ Comfortable
   - ☐ Confusing
   - ☐ Echo (reverberation)
   - ☐ Harsh
   - ☐ Clear
   - ☐ Irritating
   - ☐ Relaxing
   - ☐ Other (Please describe)

3. How would you rate your room(s) teaching environment? If you teach in more than one room please indicate for each room you teach in.

Room 1	Room 2	Room 3
☐ Just right	☐ Just right	☐ Just right
☐ Good	☐ Good	☐ Good
☐ Poor	☐ Poor	☐ Poor
☐ Very poor	☐ Very poor	☐ Very poor

4. For rooms rated poor or very poor what do you consider are the most problems in the room? Please indicate:

☐ Open plan style room
☐ Too much echo (reverberation
☐ Too much noise outside the room
☐ Noise produced by the children too high
☐ Any others

5 **Noise sources generated inside the teaching rooms**

5(a). Do you have any problems with noise created inside the rooms (including noise made by children)?

☐ Yes
☐ No
Please explain

5(b) What amount of nose generated in the teaching spaces is made by the children?

- ☐ None
- ☐ Some
- ☐ Most
- ☐ All

5(c) What times of the day or special events do you perceive noise to be the most excessive?

5(d) How much of the time during the working day (in percentage for example) do you consider noise to be too high?

5(e) Are there any conditions (weather etc) which affect noise levels?

5(f) Please identify all other sources generated inside the rooms!

- ☐ Equipment
- ☐ Moving equipment around the room (furniture scrape etc).
- ☐ Doors
- ☐ Rattling windows
- ☐ Floor (foot pounding/traffic)
- ☐ Ventilation
- ☐ Air conditioning
- ☐ Lights
- ☐ Fans
- ☐ Hi Fi
- ☐ Any others? Please indicate

6 Noise Sources Outside

6(a) Do you have problems with outside noise or noise from activities not associated with the centre? (Please include noise form other businesses etc if you share a building complex with other tenants or occupants.

Yes ☐ No ☐

6(b) Identify the sources of noise outside teaching rooms but inside Centre

- ☐ Noise from corridors (if applicable)
- ☐ Noise from other rooms or activities within centre
- ☐ Foot pounding/foot traffic
- ☐ Noise from equipment (squeaky swings, gates, doors etc)
- ☐ Others

Please explain

6(c) Identify noise sources generated outside the Centre

- ☐ Road Traffic
- ☐ Aircraft
- ☐ Rail
- ☐ Recreational vehicles and activities
- ☐ Road or earth works
- ☐ Lawn mowing
- ☐ Noise from other businesses or activities
- ☐ Dogs
- ☐ Loud music
- ☐ Other

  Please explain

6(d) What kind of noise do you find the most intrusive and annoying?

Why?

7 Effects of noise on children

7(a) How do you feel about the level of noise in the room?

7(b) How do you feel the levels of noise affects children generally?

Tick any of the following given by the interviewee

- ☐ *No effect*
- ☐ *Impairs communication between children*
- ☐ *Impairs communication between children and teachers*
- ☐ *Irritability*
- ☐ *Affects their learning ability*
- ☐ *Loss of concentration/ distractions etc)*
- ☐ *Creates behaviour problems*
- ☐ *Other*

7 (c) Do you feel the noise is too high?

7 (d) Do you think it may be harmful to the children?

7 (e) Do you think it may be harmful to the teachers?

8 **Effects of noise on children experiencing disability.**

8(a) Have you had experience with children having any one of the following special needs? Please indicate:

Indicate any given by interviewee

- ☐ Partially sighted
- ☐ Hearing loss
- ☐ Down syndrome
- ☐ Autistic Spectrum Disorder
- ☐ Asperger syndrome
- ☐ Pervasive developmental disorder
- ☐ Attention deficit hyperactivity disorder
- ☐ Giftedness (recently added)
- ☐ **Other conditions resulting in delay in development, speech and communication.**

Please indicate

8(b) For each of the above conditions you have indicated could you indicate how noise affects these children you have cared for? (additional sheets are included)

(i) Special Need _________________

8(c) Are there any sounds these children find particularly distressing?

8(d) What are the effects of noise that you have observed in these children?

Check any of the following given by interviewee

- ☐ *High levels of distress*
- ☐ *Irritability*
- ☐ *Distracts from learning tasks*
- ☐ *Creates behavioural issues*
- ☐ *Impairs learning*
- ☐ *Impairs communication with teachers*
- ☐ *Impairs communication with other children*
- ☐ *Any other effects*

8(e) Are there any strategies you can suggest from your practice and experience, which can be implemented to help these children?

8(f) In your opinion are children with special needs generally more adversely affected by noise than other children?

Yes ☐ No ☐

Comments

9 Effects of noise on teaching staff

9(a) How do you feel noise affects teaching staff? This can be your own personal experience or that related to you by colleagues.

Check any, which are highlighted by interviewee

- ☐ *No effect*
- ☐ *Creates stress*
- ☐ *Feels more irritable*
- ☐ *Tiring*
- ☐ *Uncomfortable*
- ☐ *Causes ringing in ears*
- ☐ *Feel it can adversely affect hearing*
- ☐ *Creates voice strain (from constantly raising voice over noise)*

9(b) Any other comments you would like to make?

10 Policies, procedures and further work

10(a) Does your centre have any formal policies and procedures in place regarding noise?

Yes ☐ No ☐

If yes would you mind submitting these for consideration and dissemination as part of our study? (There are likely to be excellent individual policies, the contents of which if disseminated in a generic way could be very beneficial.)

10(b) What strategies do you use to minimise noise levels in your centre?

- ☐ Quiet times,
- ☐ Compulsory sleep/rest times,
- ☐ Rostering of staff between contact and non-contact duties
- ☐ Ban on loud music or activates generating excessive noise.
- ☐ Any others
  Please explain

10(c) What low cost or cost effective strategies do you think could be implemented?

10(d) Is this an area, which needs more investigation and work?

Yes ☐ No☐

10(e) Is there any particular study or investigation you would you like to see undertaken?

10(f) What other ways can we assist teaching staff and the children?

11 **Please free to make any other comments or suggestions not previously covered.**

Building and environmental inspection/survey.

Data collected from Ministry of education public records and from investigations on unoccupied premises.

Centre code ____________________________

Type of licence ___________________________

Any conditions of licence____________________

Age of students __________________________

No of students currently enrolled

No of students permitted under ECC licence

No of staff

Any special characteristics?

Floor plan available or sketch?

Description of locational details (Comment on proximity to main roads/railway lines) Describe immediate surroundings.

Socio-economic status of area

Construction details

Permanent type /prefab light-weight timber construction.

Cladding

Roof and covering.

Presence of skylights or clearlite roofing (Noisy when raining)

Presence of ramps and walkways outside rooms (Foot Traffic)

Outdoor Areas

Playground Description

Description of predominant background noise when unoccupied

Indoor Areas
Carry out for each room used by children apart from wash rooms/nappy change areas.
Room 1 Description

Lighting

Ventilation

Heating

Noise from adjacent buildings or activities

Internal Surfaces

Floor Type Concrete pad, wooden floor on joists

Floor covering

Wall surfaces

Ceiling type

Pitched following roof line or horizontal with ceiling space

Ceiling surface

Acoustical analysis

Predominant background noise

Reverberation times (T_{60})

Location description

	T_{60}	T_{60}	T_{60}
63Hz			
125Hz			
250Hz			
500Hz			
1,000Hz			
2,000Hz			
4,000Hz			