Children and noise

– prevention of adverse effects

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National Institute of Public Health

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Preface

The National Institute of Public Health has hosted the leadership and project coordination of the project Children and Noise – Prevention of Adverse Effects. The report is a result of cooperation between a group of European partners that was formed to carry out the project. On behalf of the partners, the Institute hereby publishes the report *Children and noise – prevention of adverse effects.*

The project Children and Noise – Prevention of Adverse Effects continues the work carried out in the project Health Effects of Noise on Children and Perception of the Risk of Noise, which was supported by the European Commission under Grant Agreement No. SI2.143779 (99CVF2-601). The Institute published the report of that project, *Health effects of noise on children and perception of the risk of noise*, in 2001.

The partners in this project were:

- Marie Louise Bistrup, National Institute of Public Health, Copenhagen, Denmark (Project Coordinator);
- Lis Keiding, National Institute of Public Health, Copenhagen, Denmark (Project Leader);
- Susanne Neyen, Independent Institute for Environmental Concerns, Berlin, Germany;
- Roberto Pompoli, University of Ferrara, Ferrara, Italy;
- Peter van den Hazel, Arnhem, the Netherlands (INCHES); and
- David J. MacKenzie, Heriot-Watt University, Edinburgh, Scotland, United Kingdom.

The following people served as consultants to the project:

- Mary Haines, Royal School of Medicine, London, England, United Kingdom;
- Staffan Hygge, University of Gävle, Gävle, Sweden;
- Claus Møller Petersen, Carl Bro-Acoustica, Denmark; and
- Flemming Serup, occupational health and educational consultant, Roskilde, Denmark.

We thank the partners and consultants for their interest and cooperation.

A planning meeting took place on 24–25 March 2001 in Berlin, Germany. We thank Malthe Schmidthals, Susanne Neyen and Florian Knecht, Independent Institute for Environmental Concerns, for hosting the planning meeting.

A total of 40 people have been interviewed. We thank the interviewees for making their experience available for this project and for spending time and energy to comment on the examples of good practice. Annex 2 lists the interviewees.

We have met goodwill and understanding for the objectives of this project. Many people that heard about this project and became interested have helped with information and checking data and facts. We thank them all. We also thank the people working in the International Network on Children's Health, Environment and Safety (INCHES) for interest in and support to the project.

Marie Louise Bistrup and Lis Keiding are editors of the final report. The author(s) of the chapters and annexes are responsible for the scientific content and references for their chapter or annex. The authors are Marie Louise Bistrup, Mary Haines, David J. MacKenzie, Susanne Neyen, Staffan Hygge and Claus Møller Petersen. If nothing else is stated, chapters are written by Marie Louise Bistrup.

The partners had an opportunity to comment on all chapters. For practical reasons no occasion was established to collectively discuss all chapters. We thank the authors for their good work and commitment.

Carrying out the project has been interesting and rewarding. We hope that the examples of good practices included in this report will inspire people at all levels to engage in preventing noise in children's settings. We think that one of the challenges in public health is to create supportive and healthy environments in which noise does not adversely affect children's health and wellbeing.

We thank the European Commission for supporting the project under Grant Agreement No. SI2.298017 (2000CVG2-608) from the programme on Pollution Related Diseases administered by the Health and Consumer Protection Directorate-General. The European Commission has provided 70% of the funding for the project. We thank the National Association of Hearing Impaired in Denmark (Landsforeningen for Bedre Hørelse) for providing supplementary funds for this project. We thank the partners for their contributions and commitment and for providing funding for 30% of their time spent in the project. The National Institute of Public Health, Denmark has provided the remaining funds for the project.

The contents of this publication do not necessarily reflect the opinion of the European Commission, Health and Consumer Protection Directorate-General.

We thank Jens Steensberg, Ph.D., Medical Officer Emeritus, Denmark for encouraging this research and for reviewing the first draft of the report. We thank Dan Hoffmeyer, DELTA Acoustics & Vibration, Denmark, for reviewing the final draft of the report. We thank David Breuer for thorough text editing of the manuscript.

We appreciate that Marie Louise Bistrup within the given economic and time frames of the project has succeded in doing an admirable job with coordinating the whole project, interviewing several persons in the participating European countries, writing a great part of the report and being the main editor of the final report.

December 2002

Lis Keiding	Mette Madsen
Project Leader	Deputy Director

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Summary and recommendations

1. Introduction

The project Children and noise – prevention of adverse effects aimed:

- To contribute to better public understanding of the role of noise in children's health and well-being;
- To collect, critically review and disseminate examples of good preventive public health measures to protect children's health and well-being from the adverse effects of noise; and
- To improve selected methods for disseminating knowledge on how to prevent the adverse effects of noise among children.

Effects of noise
Harmful effects of noise on children consist of auditory and non-auditory effects. Auditory effects are reduced or impaired hearing or temporary threshold shifts or tinnitus. Non-auditory effects of noise are mainly cognitive effects. Thus noise can negatively affect children's learning and language development, can disturb children's motivation and concentration and can result in reduced memory and in reduced ability to carry out more or less complex tasks. Noise may provoke a stress response in children that includes increased heart rate and increased hormone response, and noise may disrupt sleep and hinder needed restoration of the body and brain. As an indirect effect of noise a raised voice may lead to hoarseness and vocal nodules.

The methods
The main approach towards achieving the aims of the project was to work with partners with experience in preventing noise in selected settings. The two main methods of gathering information were:

- Reviewing literature and published research results
- Interviewing key people

Literature search of recent intervention studies published in scientific journals and conference proceedings were included, and each author was responsible for retrieving literature and for providing references. As it was estimated that little research and evidence are published on the effects of preventing noise, it was decided also to look for unpublished manuscripts and ongoing projects. In this connection effects of prevention of noise on children's exposure as well as on children themselves were found relevant. To get around the barriers of unpublished results experts were involved as partners, and key persons, identified by the partners and the project leadership, were interviewed. Interview was chosen instead of a self-administered questionnaire to optimize the answering of the questions necessary to describe good examples of preventive measures.

In total 40 key persons, identified by the partners, were interviewed by the project coordinator. The partners participated in a number of interviews. The interviews were based on a structured questionnaire and the results of the interviews appear in the general text and in examples of good practice.

Examples of good practice
The criteria for including examples of intervention as good practice was that the intervention was evaluated, by assessing the situation before and after an intervention. The report contains an overview of 8 large intervention studies from literature and a range of examples from reports and interviews. A common framework for reviewing the intervention was used to present those examples of good practice that were collected from interviews. In total 14 examples have been chosen as good practice for selected settings and for information and awareness raising activities.

The report
The report comprises a summary and recommendations, 8 chapters and 9 annexes. Chapters 3-7 are written independently by main authors based on their – predominantly national – expertise. The summary, Chapter 1, 2 and 8 are written by the project coordinator. Annexes 3, 6, 7 and 8 are written by consultants or partners. All text was commented on by the partners and the project leadership.

A picture book
As part of this project partner Susanne Neyen wrote a picture book for children and adults *Gut, dass du Ohren hast, gut, dass du hörst!* (Good that you have ears! Good that you can hear!). Martina Genest illustrated the book. The text has been translated into English and is available for translation into other languages.

2. Principles for preventing noise in children's settings

There are three techniques for preventing noise:

- Reducing or eliminating noise at the source;
- Reducing or eliminating noise by installing a barrier between the source of noise and the recipient of noise;
- Reducing or eliminating the noise at the point of reception or at the human recipient.

The precautionary principle
The precautionary principle is often invoked in managing and regulating risk, because regulation can be initiated even if scientific certainty has not yet been reached but based on reasonable grounds for concern.

Policy, planning and the precautionary principle, as well as information and awareness raising activities are instruments in implementing the three techniques for prevention.

Selection of settings
Settings are chosen as the analytical view because the settings are natural areas for organisational and preventive purposes.

The project partners decided that settings must meet at least one of the following criteria:

- The exposure level is high.
- Many children are involved.
- Exposure is expected to cause harmful effects.
- Especially vulnerable groups of children are being exposed.

The project attempted to address settings in Europe with many children and settings that reflected the situation for children with normal hearing. In addition, the needs of vulnerable children and children with special educational needs such as hearing-impaired children need to be addressed in these settings. Based on these criteria three settings were chosen from identified potential settings for intervention:

- Day-care centres
- Primary schools
- Discothèques and festivals.

The rationale for choosing the first setting is the fact that more and more children use various forms of day-care systems. Many countries have well-established systems in which young children attend day-care centres prior to entering primary school. These day-care centres play an important role in the initial stages of children beginning to establish their basics of education.

Primary schools are important: irrespective of the country, children in primary school are being taught the rudiments of education, and the general environment of classrooms can play an important part in their educational process. For example, primary school children often spend long periods of time in one classroom, and a noisy room can adversely affect the occupants of that room.

Many discothèques, although they attract a certain age group, have evenings on which younger patrons can attend. The noise level can be very high in discothèques, often resulting in tinnitus or a temporary threshold shift among patrons. Many major European cities have festivals, and many of the noisier attractions inevitably appeal to younger people.

3. Examples of good practice, conclusions and recommendations for the settings

Interventions can be assessed for an effect on exposure and/or an effect on children's health and well-being. Examples of effective interventions are derived from the general literature review and from the examples from the analysis of settings.

In chapter 3 the 8 large intervention studies are reviewed. The target population studied was children of school age and of preschool age. There is sufficient evidence to suggest that chronic noise exposure at schools affects children's health and performance. The different types of intervention, assessed to benefit children's health in the large intervention studies, are included in the list of recommendations concerning planning and primary schools.

In the description of settings in chapter 4-6 the 14 selected examples of good practice, being assessed as effective and innovative, include: 4 in day-care centres, 4 in primary schools, 3 in discotheques and 3 information and awareness raising campaigns. The examples come from Denmark, Sweden, Germany, The United Kingdom, Italy and The Netherlands.

Some noise sources are unavoidable, but most noise sources can be prevented or reduced by good planning, design and implementation. Interviews with key people demonstrate the general impression that the design more often reflects the preferences of the architect or developer than the special needs of children and the perceptions of parents, staff or advisory boards.

Day-care centres
The sources and levels of background noise must be considered when locating the day-care centre. There are three main kinds of interventions: Technical, including acoustical, organisational and pedagogical, including information and awareness raising activities.

Technical interventions:

- Soft porous road surfaces can reduce traffic noise by up to 9 dB
- Noise barriers (noise walls) can be built between a day-care centre and a busy road or railway
- Traffic can be regulated to other routes or led through a tunnel
- Insulate roofs and walls and insert new windows with excellent sound insulation
- Reduce internal noisy functions such as ventilators, exhaust fans, pipes, installations and household supplies.
- Increase space and reduce crowding: Reducing the number of children per square metre or increasing the number of square metres per child reduce both noise and the burden of infectious disease
- Use room dividers to divide larger rooms into smaller areas.
- Install lightweight mineral sound-absorbing tiles on walls and in the ceiling to reduce reverberation time.

Organisational

- Get rid of noisy toys
- Place thick and loose but sturdy and washable mats or carpets on the floor
- Place thick and washable tablecloths on the tables
- Turn off or lower music from radio, TV and videos.

- Organise more silent meals
- Adopt regulations on reverberation time to include “non-designated areas” such as hallways, closets and offices, because children often play there.
- Close day-care institutions that are exposed to excessive noise from traffic
- Make children visit nature, for example a section of a kindergarten located in the forest

Pedagogical

- Reduce noise from adults: children generally view adult behaviour as an example of how to behave, and if adults raise their voices to be heard, then the children may perceive this as normal behaviour.
- Train with children to make them recognise their own noise, “good” and “bad” noise;
- Train staff in noise reduction and behaviour modification at courses or through the development workers that visit the day-care centres
- Use the sound ear: a noise-measuring device designed as a large ear and equipped with a red and a green light.

Primary schools
Many of the interventions mentioned for day-care centres are also relevant for school settings. In addition:

- Carefully design rooms considering the use of the room, the reverberation time and noise levels.
- Locate classrooms away from external noise sources, including busy hallways, cantinas and other large group areas.
- Initiate sound-insulation and noise-abatement programmes in schools;
- As part of noise-abatement programmes in schools make acoustical treatment of classrooms such as acoustic wall panels, especially applied to hard, parallel surfaces, and acoustic ceiling panels;
- Arrange the timetable so that reading classes are held in quiet times during the day;
- Introduce educational intervention to provide extra classes to train the most adversely affected cognitive skills;
- Use absorptive materials such as upholstered furniture, thick curtains and localized heavy carpeting, on the condition that hygienic considerations can be taken.

Partly open-plan schools and day-care centres
Open-plan schools and day-care centres represent special noise problems and opportunities described in annex 6 of the report.

Examples from recommendations on the acoustics are:

- Flooring must be selected based on its capacity to avoid disturbing impact noise or disturbing drum noise from footsteps in the same room;
- The reverberation time should be short;

- Constructed partitions between the functions and year groups, any partitioning being as slender as possible, and not be the full height if the sense of openness should be maintained.

Discothèques and festivals
Interventions are primarily administrative, technical and information and awareness raising activities.

Administrative measures (determination of the maximum permissible sound pressure levels):

- A law that determines a maximum sound level would impose clear limits. Compliance could be ensured through continuous sound level measurement or an integrating averaging sonometer (similar to a tachograph).

Technical measures and measures related to construction and room acoustics:

- Limit the sound emission of music devices by electronic output limiting.
- Visualise the sound volume using level lights or similar means. For example, a green light means harmless sound levels, and a red light means dangerously high levels.
- Create quiet zones in which people can converse without raising their voice (<70 dB(A)).
- Locate the loudspeakers to ensure that no one can get too close to them, reducing exposure.
- The volume of music should not be increased during the evening.

Further measures:

- Motivate youth to wear earplugs;
- Create fancy earplugs;
- Prescribe training for the operation of music devices to provide knowledge about the risk of hearing impairment from high sound pressure levels and about measures to protect the public from high sound levels;
- Carry out more education in schools.

4. Examples of good practice, conclusions and recommendations for information and awareness raising activities

Information and awareness-raising activities can and should vary in content and target groups depending on the specific situation. Political and organisational and pedagogic interventions towards specific target groups are used as measures.

Political and organisational:

- Develop and implement national, regional and local noise action plans;
- Organise activities on the International Noise Awareness Day;

- Organise yearly Ear Weeks accompanied by information about noise and possible effects of noise;
- Lobby towards members of parliament to promote the cause of preventing noise and protecting hearing;
- Establish quiet areas.

Examples of campaigns for specific target groups:

- Nationwide campaign against tinnitus;
- Folders and brochures for young people about the dangers of loud rock music at concerts and of walk- and disc-men;
- Free earplugs to children when using fireworks;
- Spread information among youth about impairment caused by loud music and promote use of earplugs.

The methods used for information and awareness raising activities include:

- Written material such as brochures, booklets, picture books, documents and popular magazines;
- Media with human voices, music and sound;
- Pictures and moving pictures, films, videos, television and interactive computer-games;
- The Internet: information for professionals and other adults, parents, interest groups and children and music for downloading;
- Questionnaires;
- Statements made by prominent people who have great appeal to young people; and
- Being present with props and promotional educational material at festivals and discothèques.

Because videos, computer games and films include sound, they are good media to illustrate sound and noise situations, in addition to pictures and the written word. The videos on dangerous toys and on tinnitus mentioned in this project have very vivid and loud examples of noise, with great effects on the viewers.

5. Summary of themes across settings

Selecting settings is primarily useful for organizational purposes but some themes are general across the selected settings. These themes are political, organizational, technical themes and experiments.

Children's susceptibility
In addition to being especially susceptible to noise, children may have or display hereditary, behavioural, mental, environmental or social problems that may be exasperated when related to noise exposure. Children who have special needs for good learning environments are especially vulnerable to noise. These special needs include: hearing

impairment, visual impairment, learning problems, a first language differing from the dominant one, and hyperactivity.

The role of adults and children
Adults are responsible for providing good living, playing and learning environments for children. Nevertheless, children are capable of observing and communicating about the "occupational" environments in their day-care centres and schools. Children's interests should be represented, and it has been proposed in Sweden to appoint adult child-protection ombudspersons, whose role it is to represent children or help children represent their special interests.

Legislation and planning
Legislation and regulation related to noise and the acoustic climate in children's settings should reflect and respect the special susceptibility of children in general and of especially vulnerable children in particular. Special legislation for children's "occupational" health could be developed as a way of ensuring children's best interests.

Planning is a crucial element in prevention of noise as a public health activity:

- Implementing policies to reduce noise emission at the source;
- Preparations of noise maps that are surveys of actual noise levels;
- Preparation of noise action plans to secure that activities do not exceed specific maximum noise levels;
- Locating noise producing functions so they do not disturb noise sensitive functions;
- Diminishing noise sensitive uses of areas close to airports;
- Reducing railway noise at the source.

Health impact assessment
Health impact assessments should consider the special susceptibility and special interests of children, which implies that the effects of noise on the health and cognition of children should be a parameter in the assessment.

Acoustic materials and hygiene
Acoustic tiles are used for achieving a specific acoustic climate or for changing an existing unsuitable one. The usual aim is to reduce the reverberation time and to reduce the background noise level. Acoustic tiles may be difficult to keep clean and could require special cleaning materials.

Materials with absorptive qualities that are good for acoustic purposes, such as curtains, furniture coverings and other fabrics as well as carpets, may be hazardous to children with asthma and allergies, because of the dust, including potential allergens from pets at home and from house-dust mites harboured in these textiles. Hygiene and maintenance of sound-absorbing material are crucial and selection of material good for both children with allergies and hearing-impaired children is preferable. Maintenance budgets should contain identifiable funds for improving and maintaining the acoustic environment.

Noise measurements
Standards and practises for noise measurements vary across Europe. Adoption of a common system may be a help when implementing and assessing interventions.

For day-care centres and schools, the period of time during which noise is measured should be the opening hours. Measuring overall and peak levels of noise in children's settings requires observing and noting the sources of noise and noise peaks so that intervention can be adequate and precise.

Training of professionals
Architects and engineers should have better education about noise and acoustic parameters, and medical officers of health and environmental health professionals should be given increased training in dealing with noise problems. Training of child-minders, child educators and teachers should include the effects of noise on children's health and cognition and information on organisational, technical and educational measures to prevent noise in children's settings.

Experiments
Experimentation and systematic assessment should be used to develop:

- Analysis and assessment by adult professionals of the settings relevant to children's "occupational" health;
- Observation and assessment by children of the settings relevant to children's "occupational" health;
- Labelling the acoustic performance of buildings that house day-care centres and primary schools, which could ultimately be integrated as a criterion within ecolabelling of buildings; and
- Labelling the noise levels of products.

Further research
Generally interventions to prevent adverse effects of noise on children need better assessment of both short and long-term effects. Among several proposals for further research, in chapter 8, a number of research items have been given a priority, based on identified gaps in research and an estimate of which interventions would benefit as many children as possible. Among important research themes are thus: Evaluation of effectiveness of intervention to reduce noise in open-plan day-care centres and schools, evaluation of effects on children's health of access to quiet zones, evaluation of the effects on children of noise in outdoor areas, determination of the period of quiet needed to restore hearing after noise exposure, assessment of the effects of the number of children in rooms or classes on noise, and assessment of the effects on children of noise from video and computer games.

1. Introduction and methods

"Noise is to the soundscape as litter is to the landscape"
Les Blumberg, Director, Noise Pollution Clearinghouse, Montpelier, Vermont, USA

The project Children and noise - prevention of adverse effects continues the work carried out in the project *Health effects of noise on children and the perception of the risk of noise*, which was supported by the European Commission 2000-2001 (Grant Agreement No. SI2.143779 (99CVF2-601).

1.1. Health effects of noise on children

Health effects of noise on children and the perception of the risk of noise (1) is a report based on the work by partners and consultants in that project. The report also provided feedback to participants of the international seminar *Children and Noise: Health Effects, Perception of Risk and Definitions of Noise* organized by the National Institute of Public Health, Denmark and held at the WHO Regional Office for Europe in Copenhagen, Denmark on 19-20 June 2000. The report included the results of the presentations and recommendations made at the seminar. Staffan Hygge has summarized the main conclusions on noise in children's settings and the effects of noise on children in Annex 3.

Harmful effects of noise on children consist of auditory and non-auditory effects. Auditory effects are reduced or impaired hearing or temporary threshold shifts or tinnitus. Non-auditory effects of noise are mainly cognitive effects. Thus noise can negatively affect children's learning and language development, can disturb children's motivation and concentration and can result in reduced memory and in reduced ability to carry out more or less complex tasks. Noise may provoke a stress response in children that includes increased heart rate and increased hormone response, and noise may disrupt sleep and hinder needed restoration of the body and brain. As an indirect effect of noise a raised voice may lead to hoarseness and vocal nodules.

Studies on risk perception, including children's own perception of noise, are essential as a background for strategies for risk communication. Definitions of noise depend on the perception of noise and on knowledge of the adverse effects of noise, including the vulnerability of children and opportunities for preventing noise and its adverse effects. Based on these considerations noise was defined as follows (1):
Noise is any sound - independent of loudness - that may produce an undesired physiological or psychological effect in an individual and that may interfere with the social ends of an individual or group.

1.2. Children and noise - prevention of adverse effects

Based on the results of the overview established in *Health effects of noise on children and the perception of the risk of noise*, the National Institute of Public Health and the International Network on Children's Health, Environment and Safety (INCHES) found it natural to continue by carrying out a project on how to avoid these effects of noise on children.

The project aimed:

- To contribute to better public understanding of the role of noise in children's health and well-being;
- To collect, critically review and disseminate examples of good preventive public health measures to protect children's health and well-being from the adverse effects of noise; and
- To improve selected methods for disseminating knowledge on how to prevent the adverse effects of noise among children.

The critical part was to gather examples of initiatives that have been evaluated before and after intervention.

The project aimed to disseminate examples on effective preventive measures and strategies for information and awareness raising. The report contains an overview of 8 large intervention studies, and 14 examples of prevention in day-care settings, in primary schools and in discotheques and examples of and strategies for information and awareness raising activities.

A related example of information and awareness raising among children and adults is the publication *Gut, dass du Ohren hast, gut, dass du hörst!* (Good that you have ears! Good that you can hear!). This is a picture book with pages for adults with facts about the ear, noise and hearing protection alternating with pages for children based on integrating stories, rhymes and pictures about the same topics. The publication is available at the Independent Institute for Environmental Concerns in Berlin: Unabhängiges Institut für Umweltfragen e. V. (UFU), address is in Annex 1. As part of this project the text has been translated into English and is available for translation into other languages with publication of a national version of the picture book in mind.

1.2.1. Criteria for selecting settings for children

The United Nations Convention on the Rights of the Child defines a child as a person up to the age of 18 years. The project includes children from the age at which they can start day-care (a few months) and until they become 18 years old. Children in vocational training are not included in this project, but all other settings for children are potentially of interest, and criteria for selecting the settings to be included in the study were developed.

The project partners decided that the selected settings must meet at least one of the following criteria:

- The exposure level is high.
- Many children are involved.
- Exposure is expected to cause harmful effects.
- Especially vulnerable groups of children are being exposed.

1.2.2. Selection of settings

The partners have worked in various fields related to noise and preventing noise and drew on this expertise to prepare a list of potential settings. The following list of potential settings and points of intervention was developed:

- The home and children's daily activities
- Children's hospitals, including intensive care units
- Toys in various situations
- Recreational areas
- Leisure activities
- Day-care centres
- Primary schools
- Schools for hearing-impaired children
- Music schools
- Secondary schools
- Sporting centres
- Discotheques and festivals
- Children living on river-boats
- Bars and cafes.

The project attempted to address settings in Europe with many children and settings that reflected the situation for children with normal hearing. In addition, the needs of vulnerable children and children with special educational needs such as hearing-impaired children need to be addressed in these settings. Based on these criteria and the list, three settings were chosen:

- Day-care centres
- Primary schools
- Discotheques and festivals.

The rationale for choosing the first setting is the fact that more and more children use various forms of day-care systems. Many countries have well-established systems in which young children attend day-care centres prior to entering primary school. These day-care centres play an important role in the initial stages of children establishing their basic language and social skills.

Primary schools are important: irrespective of the country, children in primary school are being taught the rudiments of education, and the general environment of classrooms can play an important part in their educational process. For example, primary school children often spend long periods of time in one classroom, and a noisy room can adversely affect the occupants of that room.

Many discotheques, although they attract a certain age group, have evenings on which younger patrons can attend. The noise level can be very high in discotheques, often resulting in tinnitus or a temporary threshold shift among patrons. Many major European cities have festivals, and many of the noisier attractions inevitably appeal to young people.

1.3. Methods

The main approach towards achieving the aims of the project was to work with partners with experience in preventing noise in selected settings. The two main methods of gathering information were:

- Reviewing literature and published research results
- Interviewing key people

Each author was responsible for retrieving literature and for providing references. As it was estimated that little research and evidence are published on the effects of preventing noise, it was decided also to look for unpublished manuscripts and ongoing projects. In this connection effects of prevention of noise on children's exposure as well as on children themselves were found relevant. To get around the barriers of unpublished results experts were involved as partners, and it was planned that key persons, identified by the partners and the project leadership, should be interviewed.

1.3.1. Reviewing literature and published research results

To identify relevant literature references on children and noise, prevention of adverse effects, the partners supplemented their a priori knowledge on references with literature search on the internet for studies in specialized literature and scientific journals and other sources of knowledge appearing on the internet, as well as reports and proceedings from relevant conferences and surveys from colleagues. Consultations with international experts and specialists within certain areas were conducted to make sure to be up to date with relevant references and to select references that were acceptable from the specialist point of view, as well as inquiries to the state institutions and official departments on topics such as relevant laws and guidelines etc.

1.3.2. Interviews with key persons

Interview was chosen instead of a self-administered questionnaire to optimize the answering of the questions necessary to describe good examples of preventive measures.

The partners and consultants identified for interviewing potential key people who had specific experience in preventing noise in the three settings. The key people included persons involved in measuring noise, preventing noise, acoustics, child-care, education and other relevant fields. The professional backgrounds of the key persons that were interviewed were engineers, some of whom with special education in acoustics, headmasters, child educators, representative of interest groups or national and local government officials and researchers.

The interviews were conducted on the basis of structured questionnaires, one for each setting. An introductory letter and the questionnaire were sent to all key persons prior to the interview. The interviews lasted 2 hours on average. The interviews were conducted in English, German or Danish, and in a few instances a joining partner from the country in question assisted as interpreter. The results of the interviews are included in the general text in each setting or in examples of good practice. An example of a questionnaire is enclosed as Annex 4.

In total 40 people were contacted and all agreed to be interviewed. All key persons but one were interviewed by the project coordinator, and in 15 instances with the participation of a partner or consultant. The results of the interviews were entered directly into a portable computer and edited later. Interviewees supplied additional material, usually written in the national language.

1.3.3. Systematic review of preventive measures

The examples that were identified to be good practice collected from the interviews were reviewed systematically to document the effectiveness of the intervention. At the planning meeting in Berlin in March 2001, two kinds of examples were suggested:

- Examples of good practice that have been evaluated and documented using measurement before and after the intervention; and
- Examples and ideas that have been carried out but without published documentation of effects but with a potential for future good practice.

It was decided to systematize the review of examples of good practice according to the common framework for reviewing preventive measures developed by the National Institute of Public Health (Annex 5).

1.3.4. Examples of good practice

Examples of prevention appeared from a review of 8 large intervention studies, chapter 3, and were identified from literature and the interviews, as described in chapters 4-7 on settings and on information and awareness raising activities. From the interviews a total of 14 examples of good practice are included in this report: 4 about day-care centres, 4 about primary schools, 3 relevant to discotheques and 3 about information and raising awareness.

1.3.5. Concerns about methods

Key persons in 6 countries were identified and interviewed. This process was time consuming since the schedule of several experts needed to be coordinated and much travel was needed. Each partner made efforts to identify a key person for each setting, but this was not possible in all countries. A problem with the method of interviews was that funds were not allocated for reimbursing interviewees for time spent on interviews.

It is important to realise that this report includes information and experience from several member states of the European Union and as such represents a variety of cultures, traditions and regulative approaches. The examples of legislation and guidelines and of noise measurements and expressions about noise also represent national differences. The use of acoustic and noise expressions are the responsibility of each author.

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1. BISTRUP ML, ed. *Health effects of noise on children and the perception of the risk of noise*. Copenhagen, National Institute of Public Health, 2001.

2. Principles for preventing noise in children's settings

by Marie Louise Bistrup

The project Health Effects of Noise on Children and Perceptions of the Risk of Noise concluded as follows (1).

Current scientific knowledge is inadequate to predict that any particular individuals, including children, can safely be exposed to a certain level of sound. Strategies to prevent damage from sound exposure should include limiting loud and potentially hazardous sound emissions, using individual hearing protection devices, education programmes beginning with school-age children, consumer guidance, increased noise labelling of products and hearing conservation programmes for occupational settings.

This report describes concepts related to preventing noise and the effects of noise.

2.1. Instruments for preventing noise exposure

There are three techniques for preventing noise:

- Reducing or eliminating noise at the source;
- Reducing or eliminating noise by installing a barrier between the source of the noise and the recipient of noise; and
- Reducing or eliminating the noise at the point of reception or at the human recipient.

Regulation of noise is part of the policy and planning instruments.

The principles for preventing noise that can harm children's health and well-being interact in the implementation of these instruments and techniques and can be inspired by the examples mentioned in this report.

2.2. The precautionary principle

The precautionary principle is often invoked in managing and regulating risk, because regulation can be initiated even if scientific certainty has not yet been reached but based on reasonable grounds for concern. Two definitions are available: the Rio definition and the Wingspread definition. The Rio definition (2) focuses on preventing degradation of the environment and not harm to human health.

> Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.

A group of 32 scientists, policy-makers and activists gathered in Wingspread, Wisconsin, USA in 1998 and developed a definition of the precautionary principle with four parts (3).

1. People have a duty to take anticipatory action to prevent harm.
2. The burden of proof of harmlessness of a new technology, process, activity, or chemical lies with the activity's proponents, not with the general public.
3. Before using a new technology, process or chemical, or starting a new activity, people have an obligation to examine a full range of alternatives, including the alternative of doing nothing.
4. Decisions applying the precautionary principle must be open, informed and democratic and must include affected parties.

The Wingspread definition includes the dimension of harm to human health (3):

"Where an activity raises threats of harm to the environment or human health, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically".

The European Union describes the potential scope and application of the precautionary principle within the Union beyond the environment (4):

Although the precautionary principle is not explicitly mentioned in the Treaty except in the environmental field, its scope is far wider and covers those specific circumstances where scientific evidence is insufficient, inconclusive or uncertain and there are indications through preliminary objective scientific evaluation that there are reasonable grounds for concern that the potentially dangerous effects on the environment, human, animal or plant health may be inconsistent with the chosen level of protection.

2.3. Policy

A clear policy on and political commitment to preventing noise are prerequisites for and strong tools for implementing all other measures to prevent noise. International agreements, such as international standards, can play a role in promoting or hindering measures to prevent noise. Background documents such as the 1996 *Green paper on future noise policy* of the European Commission (5) and proposals for binding international agreements, such as a draft European Union directive on the assessment and management of environmental noise (6), can set the framework or establish standards for policy and strategies to prevent noise. Publications from the World Health Organization (WHO) serve as background documents for setting standards, and publications and policy statements from WHO may also inspire national and local governments in preventing noise. *Guidelines for community noise* (7) is cited frequently as an authoritative publication (Table 2.1).

Table 2.1. Selected guideline values recommended by WHO for the environments relevant to day-care settings and other situations in which children are frequently exposed to noise

Specific environment	**Critical health effects**	**L_{Aeq} (dB)**	**Time base (hours)**	**L_{Amax} fast (dB)**
School classrooms and preschools indoors	Speech intelligibility, disturbance of information extraction, message communications	35	During class	-
Preschool bedrooms, indoors	Sleep disturbance	30	Sleeping time	45
School playground outdoors	Annoyance (external source)	55	During play	–
Ceremonies, festivals and entertainment events	Hearing impairment (patrons: <5 times per year)	100	4	110
Music through headphones or earphones	Hearing impairment (free-field value)	85[b]	1	110
Impulse sounds from toys, fireworks and firearms	Hearing impairment	–	–	140[a]

Source: adapted from Berglund et al. (7)

[a]Peak sound pressure (not LAmax, fast), measured 100 mm from the ear.

[b]Under headphones, adapted to free-field values

This report refers to these guideline values. Several countries have adopted the guideline values as national targets or standards.

In 1989, the WHO Regional Office for Europe organised the First European Conference on Environment and Health. Every 5 years, European Ministers responsible for Environment and for Health meet to discuss strategies and policy on environment and health, and to adopt statements or declarations. The Declaration of the Third Ministerial Conference on Environment and Health in 1999 contained a special section on protecting children from harmful environmental exposure (8). Many countries develop national environment and health action plans as a tool for preparing more specific objectives for environment and health.

Countries can prepare noise action plans or include noise reduction in the national environment and health action plans. The WHO Regional Office for Europe prepares a series of pamphlets with practical advice for local health and environment authorities. *Noise and health* (9) and *Acoustic measurement* (10) have been published, and a pamphlet on noise in schools has been announced.

Other documents address measures to reduce noise. In 2000, Norway's Storting (parliament) adopted a national strategic objective (11): noise problems must be prevented and reduced to protect people's health and well-being. This objective is to be achieved and measured through the following target: noise annoyance must be reduced by 25% before 2010 compared with 1999 (12). The Swedish government adopted the following target on noise in 2001 (13, 14): "By 2010 the number of people who are exposed to traffic noise in excess of the target values approved by Parliament for noise in dwellings will have been reduced by 5% compared with 1998." In Denmark, efforts are being made to prepare a new national action plan against noise (15–17).

2.3.1. Risk assessment

Risk assessment has become part of the technical and political process, involving steps to decide the level and kind of prevention and protection needed for specific types of exposure to environmental emissions or exposure.

Risk assessment can comprise:

- Assessment of the hazard: is the exposure harmful and how?
- Assessment of exposure: how much are which people being exposed to?
- Quantifying the risk: given the potential harm and the exposure, how great is the risk (based on the dose–response relationship)?
- On the basis of the results of the risk assessment, the managing of the risk in the shape of political decisions on preventive measures, can be made.

No references focusing specifically on risk assessment related to children and noise were found. Children's "occupational" environments (analogous to work environments for adults) do not seem to have been considered an interesting or important setting, and it has not been scientifically documented in which exposure situations children are less, more or equally susceptible to noise compared with adults. Noise limit values that are seen as appropriate for adults, such as allowing exposure up to 80 dB(A) on a daily basis in some countries, may not be relevant to children. Precise noise limit values may also provide an unwarranted sense of accuracy and security.

Political decisions on risk management might give high priority to including the precautionary principle to protect children adequately from potentially harmful noise.

2.3.2. Risk perception

Children may not perceive noise as the greatest environmental threat, but neighbourhood noise is considered annoying, and children feel that they have little control over noise, especially from traffic. Children respond reliably and consistently to questions on noise. Children may be annoyed to a degree that interferes with their tasks; some children attempt to avoid noise, but not all can do so (1).

2.4. Spatial planning and avoiding environmental noise

Avoiding exposure of children to environmental noise should already be a major objective at the stage of land-use planning and zoning. Decisions on the location of buildings and recreational areas and facilities at the regional, municipal and local levels should consider preventing children from being exposed to noise.

As an example, before a development in Scotland receives planning permission to proceed, noise levels are usually measured at and around the proposed development site to ensure that the building's occupants will not be bothered by noise. The measured levels are checked against the permitted levels issued by the government.

Settings for children should avoid locations near such noise sources as major roads, airports, railways and heavy industry. Noise from transport or industry may be avoided by placing the buildings for children's settings where they are needed and away from environmental noise. If environmental noise is preventing the ordinary use of recreational areas, day-care centres, schools and other settings used by children, it degrades the quality of the settings and shows a lack of respect for children.

The orientation of buildings is important in achieving quiet areas indoors and outdoors. If a building cannot be located optimally, at least one façade of the building should be quiet, for rooms for quiet purposes. The building itself can be designed to serve as a noise barrier, and outdoor areas for schoolyards, playgrounds and sports and recreational facilities should be placed in quiet zones.

Based on examples of the negative effects of noise on cognitive skills among children in schools close to sources of noise, including noise from traffic and especially aircraft noise, Sweden's Environmental health report 2001 (18) concludes that day-care centres and schools should not be located near substantial noise sources such as motorways, airports and noisy industry.

2.4.1. Quiet areas

A quiet area can be an area free from noise from human activities (19). One idea is that the public should be able to walk in a forest, for example, and not hear noise from human activities but hear natural sounds from birds, insects and waters.

Protecting an area from human noise requires designating quiet areas or time periods within these areas within which no such sounds should be made. This definition of a quiet area is not applicable to children's settings, where a quiet area would mean a more silent area.

Quiet areas can be applied to many aspects of city life. For example, at least one façade of a dwelling should be quiet, whereas noise may be accepted on the other side (20).

The proposed European Union directive on the assessment and management of environmental noise (6) also mentions the strategy of establishing "relatively quiet areas".

Research shows that children in classrooms located along the relatively quiet façade of a school do much better in reading and language development than do children on the noisy façade of the school (21, 22). Establishing relatively quiet areas inside a school can be useful in preventing the adverse effects of noise potentially created by people inside the building, but loud ambient noise levels outside schools are not compatible with creating supportive learning environments in such settings as day-care centres or schools.

2.4.2. Noise zones and noise mapping

One practical starting-point for regional and municipal planning to prevent noise is to establish noise zone and limits according to the destination of the land and then to prepare maps of existing noise levels, especially in urban areas. From the comparison between limits and existing noise levels an action plan can be set up in order to reduce potential noise exposure.

2.5. Prevention

Three main sources of noise are relevant in a room in a typical day-care centre or school:

- Noise created within the room (room noise);
- Noise generated in other parts of the building (internal noise); and
- Noise entering the room from outside the building (environmental noise).

Preventive strategies must address the specific sources of noise. Products such as cars, trains, planes, toys, instruments, ventilation systems and appliances, use of textiles and furniture can be improved to reduce the noise emitted.

2.5.1. Internal noise (room)

Room noise is noise generated from activities within a room, such as noise from ventilators and machines, scraping chairs, slamming doors and noise from class activities such as human voices. Measures to prevent noise may include installing silencers or sound-insulating material around ductwork or using quieter ventilation grids within the rooms, using quieter equipment or machines such as quiet printers, using sound-absorbing materials on surfaces of the room and felt pads under computers and furniture and changing the behaviour and habits of the room occupants.

2.5.2. Internal noise (building)

Internal noise may come from corridors or other rooms in which noise is produced such as music rooms, halls or gymnasiums. Preventing internal noise requires proper sound insulation between rooms including installing sound-insulating doors with appropriate seals around them, closing leaks for airborne noise, reducing the effects of impact noise by insulating floors and ceilings.

2.5.3. Environmental noise

Preventing environmental noise at the source outdoors is very difficult. This requires preventing the emission of noise at the source or preventing emission by inserting a barrier between the source and the recipient. Methods of abating transport noise include: reducing speed limits, noise barriers, building blocks used as noise barriers (providing a quiet rear side), porous road surfaces, prohibiting certain activities during parts of the day, permits, noise monitoring, road pricing and car-free areas.

Establishing noise barriers along roads and railways to reduce noise in nearby day-care centres and schools can improve the quality of the community environment. Proper sound insulation of the building elements of the façade (constructions) including installing of double-glazed (or more layers) windows, improving window frames and insulating walls and roofs help to reduce environmental noise in buildings used by children, but the noise may present a barrier of opening windows for proper ventilation of the building. An example of such a process is found in Modena (Italy) where, for an existing school exposed to railway noise, a special sliding window with a special sound-absorbing material in the metal frame and two-layer 6-mm glazing was developed. The new windows replaced single-glazing wood-framed wind and reduced noise by 24 dB (interview, Daniele Bertone and Andrea Franchini). Outside areas should be protected by noise barriers.

2.5.4. Interaction of sound waves and building elements

When a sound wave meets a building element such as a wall, floor or ceiling it can be transmitted, absorbed, and/or reflected. Transmitted sound passes through the material, absorption means that the material absorbs the sound (which is converted into heat) and reflected sound is reflected back to the room. The degree to which these phenomena occur depends on the materials used for the walls, floor, ceiling and other building elements of the room and their characteristics.

Building elements such as walls, windows, doors, and floors exhibit airborne sound insulation, which is the ability to reduce airborne sound, such as voices, traffic noise and music. Especially the airborne sound insulation of windows is important for keeping out environmental noise (24).

The resistance of a floor to the transmission of footstep noise is called impact sound insulation (25).

Suspended ceilings and acoustic wall treatments are typical absorbing materials used in buildings. The amount of absorption in a room is the major parameter of the reverberation time of the room. The reverberation time characterizes how the sound decreases in a room.

Examples of highly reflective building elements are concrete walls, solid floors and windows.

2.5.5. Building inspection

The quality of a building with regards to noise can be controlled by public authorities, as for example in Denmark, based on the building regulation (26).

Many local authorities in Scotland routinely check the sound-insulating properties of separating walls and floors before the development is occupied. This ensures a minimum standard of sound insulation between neighbours. For example, Edinburgh has a strict noise level policy that is strictly adhered to, especially in the many public bars, clubs and discothèques throughout the city.

2.6. Personal protection

Personal protection from noise exposure means protecting the recipient of noise (children in this case) through personal ear protectors (Chapter 6 and 7).

2.7. Participation in planning and prevention

Involvement of stakeholders is important in planning and carrying out preventive measures. Participatory processes for involving citizens in planning and community development have been developed in many European countries.

2.7.1. Children's participation in prevention

Adults are responsible for providing good living, playing and learning environments for children, but children are capable of observing and communicating about the "occupational" environments in their day-care centres and schools. Legislation in Sweden thus includes children in schools in the assessment of the quality of the occupational environment, and discussion is currently ongoing as to whether preschool children should be included in this activity. One can argue that children younger than 6 years should not be formally involved in traditional cooperation between employers and employees on responsibility for the occupational standard of a day-care centre.

Children's interests should be represented when preventive measures are planned, and it has been proposed in Sweden to appoint adult child-protection ombudspersons, whose role it is to represent children or help children represent their special interests (27). Children's observations and opinions about their experience can generally provide excellent ideas and proposals.

2.7.2 Children's perceptions of noise

As an example of the opinions of children attending a day-care centre, children interviewed at Melita (Copenhagen, Denmark) said that they cannot hear each other on the playground because of noise, that they sometimes get a sore throat from screaming (in order to be heard by other children or by adults) and that they could only find peace at a small spot behind a shed. The children's observations and opinions are precise and generally correspond with staff opinion about the effects of noise (interview, children attending Melita day-care centre, Copenhagen, Denmark).

Among a panel of pupils in sixth grade in Denmark (12–13 years), 19% felt annoyed by noise during lessons, 19% did not feel annoyed and 62% felt that they were sometimes annoyed by noise during lessons (28). Some children did not want to play in the schoolyard because the noise level was too high (28), and other children looked forward to coming home after school to get away from the noise (29). More than 50% of the children reported that they often or sometimes experience noise and turbulence in class; more girls than boys reported that they had a noisy class. Twenty-eight per cent of eighth and ninth graders reported being in very turbulent learning situations versus only 13% of pupils in grades 5–7. In addition, children in very noisy classes reported having headaches more often than did children in quieter classes (30).

2.8 Conclusions

Preventing noise in children's settings should be based on the special vulnerability and needs of children and should include the instruments of policy and planning and an understanding of prevention, the precautionary principle and protection. Children should be included and listened to, and they should get opportunities to observe, comment on and make proposals for their own "occupational" environment.

Clear political objectives translated into national action plans or public health programmes, guidelines, transparent and efficient regulation and control mechanisms promote priority-setting and implementation. A special challenge is to make operational models for the precautionary principle that address children's special vulnerability.

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3. Research evidence from intervention studies on the effect of change in noise exposure on children's performance and health

by Mary Haines

3.1. Introduction

Consistent research evidence indicates that chronic exposure to environmental noise leads to impaired cognitive function in children (1–3). The effects of noise on children's cognition are summarised below. For more complete details on these studies, see the chapter by Passchier-Vermeer et al. in *Health effects of noise on children and perceptions of the risk of noise* (4) and two review articles (1, 3).

Studies examining the effects of chronic aircraft, railway and road-traffic noise on schoolchildren's cognitive performance and health have found the following results in children exposed to high levels of environmental noise:

- Poorer reading ability and school performance on national standardised tests;
- Poorer memory of the type that requires intensive processing of semantic material;
- Deficits in sustained attention and visual attention;
- Poorer auditory discrimination and speech perception;
- Noise annoyance and impaired well-being;
- Moderate evidence that chronic noise exposure affects motivation, blood pressure and catecholamine hormone secretion; and
- Little evidence that chronic noise exposure affects mental health or disturbs sleep among pupils of primary school age.

The results from the few studies that have examined the effects of noise on mental health and sleep among pupils of primary school age generally find no association (5). Nevertheless, some weak associations have been found for mental health that need to be replicated (6). There is some evidence that noise may affect sleep in preschool children (7).

Intervention studies or natural experiments provide stronger empirical evidence for noise affecting children than do cross-sectional studies or anecdotal reports. In addition, the results from intervention studies can provide an evidence base to inform policies and measures to protect children from the adverse effects of noise. An intervention study or natural experiment is designed to test whether a change in noise exposure is accompanied by changes in health or performance (both improvement and impairment). The literature on intervention studies is sparse, and the research has varied in quality. The next section evaluates intervention studies to provide an evidence base to support policy and planning.

3.2. Intervention to reduce noise: effects on children's health and performance

The latest literature reviews on the effects of noise on schoolchildren (1–3) have been updated here by conducting a separate literature search of recent intervention studies published in scientific journals and conference proceedings and by consulting with international experts. These approaches increase the yield of publications and studies, including unpublished manuscripts.

The criteria for including studies here are that the level of noise has changed and the subsequent effects on children's health or performance have been evaluated. Studies that evaluate intervention by using acoustic noise surveys to quantify the change in noise exposure are included in Chapter 5. Experimental studies manipulating acute noise exposure and measuring the effects on performance also provide some evidence that intervening to reduce noise levels may have positive effects.

Chapter 5 outlines that both internal and environmental noise sources can contribute to total noise exposure in schools. Interventions to reduce internal noise largely involve acoustically treating classrooms (such as double glazing) to reduce total noise levels. The contribution of environmental noise sources, such as aircraft, road traffic and railways, can also be reduced by acoustic treatment of classrooms. In addition to these structural interventions, environmental noise sources associated with transport can also be reduced by spatial planning (such as airport terminals and roads) and regulating noise sources (such as setting limit values for transport). Intervention to reduce environmental noise levels at the source can potentially have wide-ranging effects on overall school environments, because noise exposure is reduced not only in classrooms but also in playgrounds and other learning spaces in the schools (such as halls and gymnasiums).

This section presents studies evaluating the effects of intervention to reduce both environmental transport noise and internal noise sources in classrooms. Each study is briefly outlined using the subheadings aim, design, results and contribution and study limitations. These five subheadings cover the themes to be considered in assessing the effectiveness of the intervention. The first two studies describe interventions to reduce the effects of environmental noise in classrooms (8, 9). The third study was a natural experiment in which environmental noise was reduced at the source (10–12). The fourth, fifth and sixth studies evaluate interventions to reduce internal classroom noise (13–16). The seventh and eighth studies were experiments evaluating the effects of change in acute noise exposure on children's performance (17, 18). Table 3.1 summarises the intervention studies (not the experiments) for easy reference.

3.2.1. Railway noise intervention in New York City (8, 19)

Aim. To examine the effect of a programme to reduce railway noise on children's reading scores.

Design. A field survey was conducted of 955 children of primary school age (350 in 1978 and 605 in 1981 in grades 2–6, about 7–12 years old) attending a public primary school adjacent to an elevated subway track in New York City. This study aimed to assess how placing one-inch-thick (2.54 cm) butyl-rubber pads on the rail tracks closest to the school and installing sound-absorbing ceilings affected the noise levels in the classroom and the children's performance on the California Achievement Test.

Results. The combined interventions reduced noise levels in the classrooms by 6–8 dB(A). Before the interventions, the average noise level when a train passed was 89 dB(A). Placing the rubber pads on the rail tracks reduced the average noise level to 85–86 dB(A). Installing the sound-absorbing ceilings decreased noise levels further to 81–83 dB(A). The reading ability of the children attending classes in rooms facing the rail tracks improved after both interventions. The reading scores of the children attending classes facing the railway track in the year before the noise insulation was installed were lower than those of other children attending other classes not affected by railway noise (19). Nevertheless, after the intervention another sample of children on the noisy side did not differ in reading achievement from those on the quiet side in the same school (8). Teachers and pupils reported a quieter atmosphere after the pads were installed.

Contribution and study limitations. This was the first study to demonstrate that reducing noise levels in classrooms could lead to improved reading ability. The evidence is limited by the fact that the study compared the performance of different cohorts of children attending the same school (between-subject analysis) rather than the performance of the same children before and after noise reduction (within-subject analysis).

3.2.2. Aircraft intervention in Los Angeles (9, 20)

Aim. To examine the effect of noise-abatement interventions in classrooms on the health and performance of children attending schools exposed to high levels of aircraft noise around Los Angeles airport.

Design. Cross-sectional and longitudinal reanalysis of baseline data (20) and follow-up data (9) was performed to compare the performance and health of children in noisy, noise-abated and quiet classrooms (total sample size 135).

Results. The intervention reduced noise levels by 7 dB(A) L_{eq}. The mean noise level for noisy classrooms was 70.29 dB(A) L_{eq} and for noise-abated classrooms 62.82 dB(A) L_{eq}. The noise abatement had small ameliorative effects on cognitive performance (mathematics), motivation and children's ability to hear their teachers but no effect on reading scores.

Contribution and study limitations. This study demonstrated a lack of overall benefits from noise-abatement programmes in schools exposed to aircraft noise. The authors argue that these results may be explained by three factors:

- There was attrition bias: the children in the noisy schools with the greatest impairment had migrated or refused to take part at follow-up.
- The effects of noise abatement on performance may take longer than 1 year to become evident because the effects of prolonged exposure to noise could last a relatively long time.
- Simply reducing noise in a classroom might not be sufficient to influence children's health and performance because children in schools burdened by noise tend to be exposed to noise in their whole school and home environments (playgrounds, walking to school and at home).

From a policy viewpoint, these results suggest that "it is likely that more effective noise abatement in classrooms (bringing levels closer to those in quiet schools) and decreasing noise exposure outside of school would have an increased ameliorative impact" (9). The evidence is limited by the fact that the study compared the performance of different cohorts of children attending the same school (between-subject analysis) rather than the performance of the same children before and after noise reduction (within-subject analysis). Another limitation was the small sample size, which increases the potential for selection bias.

3.2.3. Natural experiment with change in noise exposure in Munich (10–12)

Aim. To examine the effect of change in exposure to aircraft noise on the health and performance of children attending schools near the old Munich Airport (which was closed) and to study children attending schools near the new Munich Airport (which was opened).

Design. A prospective longitudinal natural experiment with a change in noise exposure after Munich Airport was relocated.

Results. The noise levels near the old airport declined from 68 dB(A) $L_{eq, 24h}$ to 54 dB(A) $L_{eq, 24h}$ after it closed. The noise levels near the new airport increased from 53 24h dB(A) $L_{eq, 24h}$ to 62 dB(A) $L_{eq, 24h}$ after it opened. After three waves of testing, the results indicated improvements in long-term memory recall and the reading test (only significant for the difficult sections of prose and word lists), and closing the old airport slightly affected short-term memory and reaction time. Strikingly, these effects were paralleled by impairment of the same cognitive skills among the children near the new airport after it opened. The same pattern of results has been reported for psycho-physiological stress indicators (systolic blood pressure and catecholamine secretion).

Contribution and study limitations. The Munich Airport Study provides the best evidence that reducing the noise level for as little as 1 year reduces noise-induced cognitive impairment (12), but further intervention studies are needed to test practical and affordable interventions, such as insulating classrooms against noise exposure in areas where environmental noise levels are unlikely to change.

3.2.4. Acoustic treatment of classrooms in a city in the United Kingdom (13)

Aim. To evaluate the effect of acoustic treatment of classrooms on the pupil's performance on speech intelligibility (words being understood) and word intelligibility (word recognition) and the teacher's perception of classroom improvement.

Design. A field survey was conducted in primary schools before and after acoustic tiles were applied to one classroom in two different samples of children attending classes in the same room.

Results. The background noise was reduced by 7–9 dB(A) L_{eq}. The measured average background level for untreated classrooms when the pupils were silent was 55.5 dB(A) versus 46.5 dB(A) in the treated classroom. The measured average background level for untreated classrooms when the pupils were working was 77.3 dB(A) versus 70.1 dB(A) in the treated classroom. Children in acoustically treated classrooms had improved speech intelligibility and improved word intelligibility.

Contribution and study limitations. This is one of the first attempts to assess how acoustic treatment of classrooms not only reduces noise exposure but also affects children's performance. This study provides preliminary evidence that children working in an acoustically treated classroom are less distracted and can perceive speech more clearly (21). The evidence is limited by the fact that the study compared the performance of different cohorts of children attending the same school (between-subject analysis) rather than the performance of the same children before and after noise reduction (within-subject analysis).

3.2.5. Acoustic treatment of preschool classrooms in New York City (14, 15)

Aim. To examine how the acoustic renovation of a day-care centre with unacceptably poor acoustic qualities affected the cognitive performance of children of preschool age.

Design. This was a natural experiment using a cohort model design with preschool children aged 4 years. Cognitive performance was measured on two different samples of children; noise exposure was assessed in the same classroom at baseline (noisy) and a year later (quiet) after sound-absorbing panels were installed in the classroom ceilings.

Results. Installing sound-absorbing panels reduced noise by 5 dB(A) on average. In year 1 before the intervention the average was 75.92 dB(A) L_{eq}. In year 2 after the intervention, the average was 70.90 dB(A) L_{eq}.The children performed better in the quiet condition on pre-reading skills (number, letter and simple word recognition), language skills and motivation tasks than in the noisy condition. Rhyming and letter-to-sound performance did not differ according to noise condition. Classroom teachers rated children in the quiet condition as having better language skills.

Contribution and study limitations. This research is unique in focusing on the interior acoustic elements of a preschool as opposed to environmental noise sources (road, rail and aircraft). This study is limited by the fact that it is cross-sectional, and the cohort design meant that within-subject analysis could not be conducted. These limitations mean that the developmental trends in language and reading skills can only be inferred.

3.2.6. Reducing noise levels using engineering measures in classrooms in a primary school in Slovenia (16)

Aim. To reduce the noise levels inside a primary school in Slovenia near a busy road through several administrative and engineering measures and to conduct an opinion poll of the teachers and pupils.

Design. A primary school was studied for noise before and after various types of engineering, administrative and behavioural intervention were applied at the school. The engineering interventions included: replacing windows, changing the traffic regime in the local area, calming traffic and insulating the gymnasium and dining hall. The administrative measures included: changing the school schedule, relocating the classrooms and reducing open-plan classrooms. The behavioural or alternative interventions included: using tablecloths and quiet plates in the cafeteria, playing classical music for background sound in various areas of the school and installing velvet curtains. The study was conducted among 271 pupils aged 3–8 years and 33 teachers.

Results. The interventions reduced the level of noise. The actual levels were not reported. Younger pupils reported greater noise disturbance before the interventions and rated the improvements after the interventions more highly than did the older pupils. The pupils complained less about the school. Test performance on annual school tests improved by 10% after the interventions.

Contribution and study limitations. This study demonstrates that coordinated interventions can reduce noise. This study is limited by the fact that health data were not collected to supplement the opinion poll.

3.2.7. Experiments examining how changing the noise condition affects performance in Düsseldorf (17)

Aim. To test the interaction between chronic exposure to road-traffic noise and acute laboratory noise on cognitive performance using children living in Düsseldorf, Germany. This investigation focused on how children exposed to chronic noise work under quiet and under noisy conditions in contrast to a control sample not exposed to chronic noise.

Design. An experimental 2-by-2 crossover design with two acute and chronic conditions. Two groups of children (one group chronically exposed to noise and the control group not chronically exposed to noise) were tested twice under two acute noise conditions (acute noise present or not present). The chronic noisy condition was defined as living for at least 2 years in the busy city centre and the control group as living in a quiet suburb.

Results. Children chronically exposed to high noise levels performed more poorly on tasks than did the control sample. There was no evidence of interaction between chronic and acute noise exposure. There was no evidence of habituation to acute noise exposure.

Contribution and study limitations. These experimental results suggest that change in acute noise exposure in the laboratory does not affect performance. The lack of habituation to acute noise exposure suggests that children living in noisy houses do not just get used to noise. These results suggest that interventions need to be tested in the field before decisions are taken about the extent to which laboratory results can be generalised to field studies.

3.2.8. Experiments examining how change in noise condition affects performance in Munich and Tyrol (18)

Aim. To test how chronic noise exposure and acute laboratory noise interact with cognitive performance and school achievement using children from the Munich Airport Study (10, 11) and the Tyrol School Study (22). This investigation addressed the question of how children exposed to chronic noise work under quiet and under noisy conditions in contrast to a control sample not exposed to chronic noise exposure.

Design. An experimental 2-by-2 cross-over design with two acute and chronic conditions was used. The two groups of children (one group chronically exposed to noise and the control group not chronically exposed to noise) were tested twice under two acute noise conditions (acute noise present or acute noise not present). These analyses were run separately with the data sets from both studies.

Results. The results from both samples of children indicate that children chronically exposed to high noise were less affected by acute noise at testing than the control children. In both analyses the children chronically exposed to noise were less affected when confronted with laboratory noise than the control sample. This implies that the chronically noise-exposed children seemed to habituate to acute noise in the laboratory.

Contribution and study limitations. These experimental results suggest that changing noise exposure in the laboratory is most detrimental to children who were inexperienced in working in noisy conditions. These results suggest that interventions should be planned concurrently with transport developments (such as considering school sites when new roads are being planned) so that the adverse effect of noise exposure is reduced for children who will become newly exposed to noise.

Table 3.1. Summary of six intervention studies

Section number and reference	**Design**	**Sample**	**Intervention**	**Change in exposure**	**Measures of outcome**	**Change in outcome**
3.2.1 Bronzaft (8)	Field survey	*n* = 350 pupils 7–12 years old in 1978 *n* = 605 pupils 7–12 years old in 1981 *n* = 10 teachers	One-inch-thick butyl-rubber pads on the rail tracks closest to the school and sound-absorbing ceilings	Total decrease of 6–8 dB(A) 89 dB(A) (average) before installation of pads and 85–86 dB(A) afterwards Noise levels reduced further to 81–83 dB(A) through ceiling intervention	Change in teaching methods Scores on the California Achievement Test	Reduced perceived noise Reduced volume of teacher's voice Improved reading ability compared with Bronzaft & McCarthy (19)
3.2.2 Cohen et al. (9)	Longitudinal and cross-sectional field survey	*n* = 135 third and fourth graders	Noise abatement in a number of classrooms	7 dB(A) reduction Noisy classrooms were 70.29 dB(A) L_{eq} (mean), abated classroom 62.82 dB(A) L_{eq} (mean)	Blood pressure Health Motivation Distractibility Reading Mathematics	Small ameliorative effects on motivation and mathematics No effect on reading scores General lack of effects of noise abatement
3.2.3 Evans et al. (10, 11) and Hygge (12)	Prospective longitudinal natural experiment with a change in noise exposure	Total 326 (range 8–12 years) Old airport *n* = 43 (control) *n* = 65 (exposed) (mean age = 10.78) New airport *n* = 107 (control) *n* = 111 (exposed)	Relocation of airport	Old airport declined from 68 to 54 dB(A) $L_{eq, 24h}$, a decrease of 14 dB(A) L_{eq} New airport increased from 53 to 62 $L_{eq, 24h}$, an increase of 9 dB(A) L_{eq}	Attention Memory Reading Motivation Annoyance Quality of life Blood pressure Catecholamines Cortisol	A long-term memory recall task and a reading test improved (only significant for the difficult sections), and rates of systolic blood pressure and catecholamine secretion declined after the old airport closed. Strikingly, these effects were paralleled by impairment of the same cognitive skills and increased levels of psychophysiological stress indicators among the children exposed to more noise after the new airport opened

Section number and reference	Design	Sample	Intervention	Change in exposure	Measures of health outcome	Change in health outcomes
3.2.4 MacKenzie & Airey (13)	Field survey	*n* = 126 Teachers and children of primary school age attending a school	Acoustic tiles	Background noise reduced 7–9 dB(A) Measured average background levels for untreated classrooms when the pupils were silent were 55.5 dB(A) compared with 46.5 dB(A) in the treated classroom Measured average background levels for untreated classrooms when the pupils were working were 77.3 dB(A) compared with 70.1 dB(A) in the treated classroom	Psychological effect of excessive classroom noise on teachers Psychological effect of excessive classroom noise on pupils Speech intelligibility Word intelligibility	Children in acoustically treated classrooms have improved speech intelligibility and improved word intelligibility
3.2.5 Maxwell & Evans (14, 15)	Natural experiment using a cohort design (the first sample in year 1 and the second sample in year 2)	Total: 90 children 3–4 years old *n* = 48 in year 1 (quiet condition) *n* = 42 in year 2 (noisy condition)	Installation of sound-absorbing panels in classroom ceiling of a day-care centre	5 dB(A) reduction (average sound level) In year 1 before the intervention the average sound level was: 75.92 dB(A) L_{eq}. In year 2 after the intervention, the average sound level was: 70.90 dB(A) L_{eq}	Pre-reading language skills (numbers, letters and word recognition) Motivation Rhyming task Teacher reports	The children performed better in the quieter condition on prereading skills (number, letter and simple word recognition) and on a motivation task than in the noise condition Rhyming and letter-to-sound performance did not differ across noise conditions Classroom teachers rated children in the quiet condition as having better language skills
3.2.6 Caric & Cudina (16)	Field survey	*n* = 271 pupils aged 3–8 years 33 teachers	Engineering, administrative and behavioural interventions applied included: replacing windows, changing the traffic regime of the local area, traffic calming, insulation in the gymnasium and dining hall, changing the school schedule, relocating the classrooms and reducing open-plan classrooms	Not reported	Noise survey Opinion poll of teachers and pupils	Younger pupils reported greater noise disturbance before the intervention and rated the improvements after the interventions more highly than did older pupils

3.3. Strength of the evidence and overall conclusions

This final section discusses the strength of the research evidence. Key issues, facts and gaps arising from this research evaluation are discussed. Finally, conclusions are drawn in relation to directions for preventive measures.

3.3.1. Interventions and natural experiments to reduce environmental noise

Three studies are known to have examined the effects of reducing noise on children's cognition: two intervention studies (8, 9) with methodological flaws that limit the extent to which they can be generalised and one well-designed natural experiment (10–12). Bronzaft (8) found that the previous differences in reading achievement between children from classrooms close to elevated train tracks and children on the opposite side of the building (19) were no longer significant following attenuation in rail noise. Noise was reduced 6–8 dB(A) by acoustic treatment of classrooms and by rubber pads on the rail tracks closest to the school. Teacher self-reports showed that they really did notice a huge reduction in noise interference. Cohen et al. (9) found that noise abatement in classrooms (7 dB(A) reduction) had small ameliorative effects on motivation and mathematics but not on reading. These intervention studies (8, 9) suffered from no comparison of reading ability before and after noise reduction; no objective measure of actual noise reduction; and insufficient sample sizes, which increases the potential for selection bias. The Munich Airport Study provides the best evidence that reducing the noise level for as little as 1 year reduces noise-induced cognitive impairment (12), but further intervention studies are needed to test practical and affordable interventions, such as insulating classrooms against noise exposure in areas where environmental noise levels are unlikely to change. The Munich study suggests that reversing noise effects in children requires reducing noise exposure by at least 10 dB(A) L_{eq} and that it takes at least 1 year of being taught in a quieter classroom before health gain can be observed.

3.3.2. Intervention to reduce internal classroom noise

The three studies evaluating interventions to reduce internal noise in classrooms provide preliminary evidence that noise reduction can lead to improved performance. The strength of the evidence is limited by the fact that the studies compared the performance of different cohorts of children attending the same school. A between-cohort comparison is less sensitive than a within-subject comparison because other differences between the samples (such as intelligence quotient, socioeconomic status or ethnicity) might confound the results; this is especially likely with small sample sizes. Future studies need to provide evidence of the benefits of sound insulation in children using a range of health and performance indicators. In conclusion, if future research confirms these preliminary results, then acoustically treating classrooms in noisy areas is likely to benefit children's performance and health.

3.3.3. Experiments assessing how change in acute noise exposure affects children's performance

Experimental studies provide the weakest evidence for good practice related to intervention to reduce the effects of noise on children. This is because experimental results must be replicated in field research before policy decisions can be taken. The results from the two studies presented conflict concerning habituation to acute noise during cognitive testing. This conflict needs to be resolved for other reasons apart from planning intervention (the conditions under which examinations are conducted in schools). The main conclusion that can be drawn from these laboratory results, given the effects of acute noise on performance among adults (23), is that acute noise does influence performance and that reducing acute noise during testing improves performance. Extrapolation from these results makes it plausible that reducing chronic noise exposure could also improve performance. This speculation must be confirmed empirically.

3.3.4. Key issues

Three key issues have emerged from the discussion of the research evidence that need to be considered when making recommendations about the nature of intervention to reduce noise effects.

Length of exposure before the onset or offset of health effects. In addition to intervention field studies, the strongest evidence for studies of noise influencing health and populations comes from longitudinal data on individuals followed up over time. This type of information can show the extent to which changes in noise are followed by changes in health. Further, these studies provide evidence on: a) habituation to exposure and b) the length of time required before effects are reversed if noise exposure changes. There are few of these studies in the noise and health literature, not least because they are difficult and expensive to carry out. The results from the two repeated measures studies conducted in Los Angeles (9, 20) and London (5, 24) demonstrate that children do not adapt to chronic noise exposure. These results are potentially important and need to be replicated because they suggest that noise reduction is critical if the patterns of adverse effects of noise exposure are to be reduced. It is still unknown how long it takes for these effects to be reversed if noise exposure is reduced.

The reduction in noise exposure required to observe health gain. WHO recommends guideline values for school noise exposure of 55 dB(A) L_{eq} for outdoor levels and 35 dB(A) L_{eq} for indoor levels (25). These targets were set to reduce noise annoyance from outdoor noise exposure and to improve speech intelligibility indoors. The research results seem to indicate that interventions need to reduce noise exposure by at least 7 dB(A) before improvement becomes evident. Nevertheless, if the noise level is very high before the intervention, a larger reduction than 7 dB(A) may be required to produce health gain. Given the WHO guidelines (25) and the results from the intervention studies, it can be tentatively concluded that noise should be reduced by at least 7 dB(A) L_{eq} and ideally comply with the WHO limit values for an intervention study to be sensitive enough to detect improvement in health.

Can the adverse effects of noise on children be reduced by other types of intervention apart from reducing noise? Intervention can be costly and reducing noise at the source can be very difficult. This raises the question of whether other types of intervention may be effective in preventing the adverse effects of noise among children. Identifying mechanisms to account for noise effects could provide a theoretical basis to design interventions that intervene between noise exposure and outcome. The theoretical understanding of the effects of noise on children is limited, because very few studies have actually tested the mediating role of a hypothesised factor. The relationship between cognitive main effects and cognitive mechanisms is complex, because these factors tend to be interrelated (1). Moreover, it is plausible that more than one construct mediates between noise and children's cognition. The most theoretically plausible mechanisms to account for reading deficits are psycholinguistic mediators, because they have been shown to be robust in accounting for the acquisition of reading skills (26). Further, preliminary empirical evidence supports these psycholinguistic hypotheses (26, 27). Two studies have conducted appropriate analysis for the mediating role of psycholinguistic processes, auditory discrimination (27) and speech perception (26). Focusing on the underlying mechanisms not only furthers theoretical knowledge of noise effects but could also be used as a starting-point for intervention (such as educational intervention). This may be necessary when altering the predictor variables is difficult because they are environmental stressors such as exposure to aircraft noise.

3.3.5. Facts

- Sufficient evidence suggests that chronic noise exposure at schools affects children's health and performance.
- The potential negative and positive effects of interventions have been researched to a limited extent.
- Adverse effects in children exposed to high levels of noise seem to be able to be reversed if noise is reduced by at least 7 dB(A) L_{eq}. Detecting benefits requires children being in quieter classrooms for at least 1 year. This needs to be confirmed by future research.
- Noise effects are likely to be reversed more effectively if noise-abatement programmes in classrooms are combined with decreasing schools' exposure to environmental noise.

Gaps

- Well-controlled large-scale studies need to evaluate sound-insulation programmes to determine how they affect a range of performance and health effects associated with children's exposure to noise.
- Future studies need to evaluate the protective and restorative effects of accessibility to quiet zones (or of the possible options for protecting such quiet zones, such as natural areas and parks) on children's health.

- Well-controlled large-scale studies need to evaluate policies and regulations to reduce noise exposure to determine how they affect a range of performance and health parameters in children associated with exposure to noise.
- Studies are required to provide more precise insight into the mechanisms that underlie the effects of noise on children.

3.4. Conclusion

This chapter evaluated the research on a range of preventive measures. These measures have included acoustically treating classrooms, relocating airports and reducing railway noise at the source. The target population studied was children of school age and of preschool age, and the setting was schools. There is sufficient evidence to suggest that chronic noise exposure at schools affects children's health and performance. Since research results are consistent, it may be wise to apply the precautionary principle for improving the school environment around airports and transport installations using the recommended WHO noise limit values as guidelines (25). Using these WHO noise levels would permit the number of children at risk of non-auditory health effects from noise exposure at school to be determined. The potential negative and positive effects of interventions have not been thoroughly researched because few high-quality studies have been conducted. The research evidence alone is therefore not strong or conclusive enough to provide a basis for developing policy. Subject to evaluation, the following types of intervention might, however, benefit children's health:

- Initiating sound-insulation and noise-abatement programmes in schools;
- Implementing policies to reduce noise emission at the source;
- Organising classrooms within schools so that learning environments are placed in the quietest sections of schools;
- Arranging the timetable so that reading classes are held in quiet times during the day; and
- Educational intervention to provide extra classes to train the most adversely affected cognitive skills such as reading and memory (Chapters 4, 5 and 6 describe in detail cases in which noise has been effectively reduced in children's settings).

The development of these interventions must concur with thorough research evaluation to determine the efficacy of the intervention in reducing noise exposure and in reducing its adverse health effects on children.

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4. Preventing noise in day-care settings

by Marie Louise Bistrup

Good that you have ears! Good that you can hear!

Childhood is increasingly being institutionalised. This increases the effect of the institutions in which children spend their daily lives. Children in many European countries are exposed to noise for considerable time each day in day-care settings, and ways of creating day-care settings with less stress and more peace need to be examined.

4.1. Main effects of noise

Noise in day-care settings may disrupt the communication of information that is important for the child's language comprehension and development, may influence social and cognitive maturity and may prevent the child from understanding important safety messages. Studies show that some children in noisy environments may learn to tune out auditory stimuli but in a non-discriminatory way so that they also tune out important messages (1).

Noise can originate from many sources at the same time, and this load of noise serves as the background for social life and learning in day-care settings. Children's voices tend to have a high frequency and often have a sharp pitch that may be more annoying than the deeper voices of adults. Children adjust their voice level to the ambient noise level. Generally improving the acoustic quality and reducing noise levels in day-care settings can improve hearing, understanding and communication and reduce stress, which can lead to a quieter environment and improve the quality of life, also for the adults present.

4.2. What are day-care settings?

For preschool children, day-care settings include day-care centres that have different tasks and different names, such as: nursery schools, day nurseries, crèches, child-minders, play school, play groups, kindergartens and preschool centres. The day-care service can cover the whole day or only part time. For schoolchildren, the day-care settings are after-school centres and/or after-school classes.

4.3. Character of and background for day-care centres

The character and use of day-care centres vary in Europe, and the age groups attending day care differ between countries. The child's age of debut at a day-care centre depends on social and cultural factors such as the length of maternal and paternal leave, the participation of women and men in the labour market, the price, availability and perceived quality of day-care centres, the age at starting school and family preferences.

Children may also attend day-care centres before and after school. Since many schools are developing into schools lasting the whole day, the acoustic and noise regulations applying to the rooms used for teaching purposes may be inconsistent with those applying to leisure activities in after-school centres or classes. Such rooms must be designed for multiple purposes, and room acoustics and sound insulation must be considered.

4.3.2. Cultural and local differences

Young infants are usually taken care of in the home by a member of the family. If both parents participate in the labour market, they may need to find a place outside the home to care for the child.

Denmark. In Denmark, most mothers and fathers have paid employment, and families start looking for day care after the child is born. Typically the child starts in family day care in a private home, which is privately run but publicly controlled family care for children between 6 and 12 months of age. Day nurseries are centres for children between 6 months and 3 years, and children usually start in kindergarten at 3 years and continue to 6 years of age. Some centres integrate care for children from 6 months to 6 years of age. Young children usually sleep in a pram or push-chair during the day, and this is usually outdoors but is not recommended when temperatures are below 10°C.

The number of children taken care of in public arrangements has been increasing in recent decades. In 2000, 56% of children aged 0–2 years and 94% of children aged 3–5 years attended municipal day care. The children aged 0–5 years were enrolled as follows: 20% in kindergartens, 1% in age-integrated centres, 63% in family day care and 16% in day nurseries or after-school centres. The children aged 3–5 years were enrolled as follows: 57% in kindergartens, 35% in age-integrated centres, 5% in family day care and 3% in day nurseries or after-school centres (2).

United Kingdom. In the United Kingdom, day care is for children up to the age of 5 years, when they start school, or after school for children up to 8 years. Day care is provided in private homes and in centres. Child-minders are self-employed and take care of children in their private home. A child-minder must participate in a 10-week training course before getting a licence. Day-care advisers have an inspection and advisory role.

Germany. Germany has a difference between *Kindergarten*, at which children receive care for up to 5 hours per day, and *Kindertagesstätte*, which is for the full working day. An estimated 70–85% of children attend day-care centres for more than 5 hours a day. Day nursery for very young children is a less frequent type of day care (interview, Carsten Ruhe).

Italy. Children in Italy may attend nursery (*nido*) from the age of 4–6 months until they are 3 years old, and continue in kindergarten (*materna*) until they start school at about 6 years of age. The need for day-care centres is increasing, and some concern about noise in kindergartens has been raised and dealt with. Maternity leave is 5 months at full salary with the option of extending it to 12 months at reduced salary.

The Netherlands. In the Netherlands, children start school at age 4 or 5 years. Starting in August 2002, all children in the Netherlands attend school when they turn 4 years old. Centres are often clustered into complexes, with schools and preschool and school-age day-care centres, social welfare facilities and adult education.

Sweden. In Sweden, maternity leave lasts 12 months, and children are involved in day care from the age of 12 months to 6 years. In the 1970s, it was customary to design and build kindergartens with a large central room or hall for playing, and adjacent rooms for other functions. One child educator said that it was often impossible to make oneself heard when all the children were present, and the only thing to do was to get away to avoid the high sound levels. Over time, the child educators learned how to use the large play hall in a less noisy way (3).

4.3.3. Objectives of day care

The objectives of enrolling a child in day care vary between countries and according to the individual preferences of parents. Typical objectives include: allowing both parents to take paid employment or to study; educating the children to become creative or academically trained; and developing social, democratic or religious attitudes. Different ideologies can lead to special requirements for the physical environment. For example, day care based on Montessori principles emphasises the unique development of the individual child and encourages children to play individually in silence, and this requires an especially good acoustic climate. Children raised according to anthroposophical principles (Rudolf Steiner) play with specially designed toys for various age groups or stages of development, and the centre may emphasise the need for experiencing and knowing the yearly cycle and developments in nature. A day-care centre in the countryside has greater opportunities for experiencing peace and quiet and sounds from nature than a centre in the middle of a city.

Parents and the child educators frequently want children to become curious, interested and responsible, which leads to searching, active and more noisy behaviour.

The different objectives for day-care centres should influence the perception of how design and acoustics can support such objectives. However, the interviews with key people demonstrate the general impression that the design more often reflects the preferences of the architect or developer than the special needs of children and the perceptions of parents, staff or advisory boards.

For day-care centres, the general problem is not that children cannot find places to be noisy and rowdy but that children have difficulty in finding quiet places with space for peaceful activities.

Denmark has about 500 nature kindergartens. The children are outdoors in the forest for most of the day and have an indoor space in a cottage or simple building. The day usually starts and ends at a collective meeting-place in town with transport to and from the forest by bus.

A study in Sweden documents that children in nature kindergartens are more harmonious and have fewer days off sick, better motor development and better concentration than children in urban kindergartens (4). The children disturb each other's play less than do children in urban day-care centres. A list of the advantages that nature kindergartens give children has the following ranking:

1. More space;
2. Fresh air and considerable daylight;
3. Less noise; and
4. Less stress.

Children in nature kindergartens tend to be social and caring, but because the children are used to being rowdy and expressive they make more noise when they are inside (5). A contrasting observation is that children in nature kindergartens are quieter and that children in urban day care are noisier (interview, staff, Melita Kindergarten).

4.3.4. Design and children's needs

Children need to use their bodies to perceive the world and learn about their own body and self. They need to play both vigorously and quietly; they need to socialise as well as to find peace and quiet. The design of children's environments does not always honour these developmental needs, which also include being able to hear and be heard, to shout when necessary and to find peace and quiet when they are needed or requested. Children need well-designed outdoor areas, green areas, fresh air and good experiences.

4.4. Examples of regulations of noise

This section on examples of regulations of noise is based on examples of legislation, guidelines and regulations for the individual member state, that during the interviews have been mentioned as important. The description is not based on a systematic overview of noise regulation but illustrates a variety and a level of difference between members states.

4.4.1. Denmark

The rules laid down in the 1995 Danish Building Regulations (6) relate to day-care centres built in 1995 and afterwards. Section 9.4 states that, for general activity rooms, the average reverberation time in the frequency range 125–2000 Hz should not exceed 0.6 seconds. This applies to nurseries, kindergartens and after-school centres. (7).

Noise levels from traffic around day-care centres are regulated through planning legislation and guidelines from the Ministry of the Environment. Day-care centres have the same status as residential areas; generally noise from traffic measured in front of the building should not exceed 55 dB(A), but in special circumstances noise up to 65 dB(A) can be accepted. For outdoor areas, noise levels should not exceed 55 dB(A).

Noise inside day-care centres from ventilation and heating systems, pipes, drainage is not regulated, but ought to not exceed 35 dB(A).

4.4.2. United Kingdom

Standard 4, Physical environment, a standard with a potential relation to noise, states (8): “The premises are safe, secure and suitable for their purpose. They provide adequate space in an appropriate location, are welcoming to children and offer access to the necessary facilities for a range of activities, which promote their development”. For day-care centres, an additional standard states that “Provision is made (space or partitioned area) for children who wish to relax or play quietly, equipped with appropriate furniture. This area may be converted from normal play space, provided children can rest safely without disturbance.”

4.4.3. Italy

The Framework Law on Noise Pollution (9) establishes all the general nationwide rules governing noise pollution. It lays down the specific competence of the state, the regions, the provinces and the municipalities and their duties (such as prevention, monitoring action plans and enforcement).

A presidential decree (10) classifies noise zones into six classes with different levels for daytime and night time exposure. The first zone is especially for protected areas, including schools, and the permissible levels of environmental noise in these areas are 50 dB(A) for daytime and 40 dB(A) for night-time.

Another presidential decree (11) details the passive acoustic requirements for buildings and installations with the aim of reducing human exposure to noise. Table 4.4 in section 4.11.3. shows the minimum values required for building elements and installations for different types of buildings: schools are classified in category E. Regions can decide to adopt stricter standards.

4.4.4. The Netherlands

Noise and acoustic climate in day-care centres in the Netherlands are regulated by legislation on buildings for educational purposes (see Annex 8).

4.4.5. Sweden

The regulations on day-care centres in Sweden (12) are almost identical to the regulations regarding schools. These regulations lay down maximum acceptable noise levels from ventilation and installations and guideline values for the insulating qualities of walls, floors etc. The guidelines for insulation values for airborne noise between rooms for rest and other rooms is (R'_W (weighted apparent sound reduction index) 48 dB), and the impact sound levels in rooms for rest is ($L'_{n,w}$ (weighted normalised impact sound pressure level in the field) 64 dB). The guideline value for the maximum level of indoor noise from traffic is 30 dB(A) for classrooms and 35 dB(A) in group rooms, libraries, offices and other rooms (13).

A reverberation time of between 0.5 and 0.6 seconds is recommended in Sweden (see Annex 7).

4.5. Special needs

4.5.1. Lighting and speech

Speech perception is strongly influenced by the visual perception of faces, especially mouth movement, and good lighting is therefore important for enabling young children to see the facial and body expressions belonging to words and phrases. For this reason, lighting in children's settings should be considered part of creating a good acoustic environment. Day-care centres should be designed to allow ample natural light into rooms.

4.5.2. Vulnerable children

Developing language and social skills is even more important for very young children than for schoolchildren, who are expected to have already mastered the basics of language. In noisy day-care centres, children may not hear the spoken word properly and may not reproduce specific words or sounds correctly. By not hearing what is being said, children miss important information that may be relevant to their activities, behaviour or safety. For children who have temporary hearing impairment, such as that resulting from a cold, or have learning or social problems, the level of noise and the acoustics within rooms can adversely affect their language and social development.

Kindergartens are often used to integrating children with different ethnic backgrounds coming from homes whose main language differs from the dominant language in society. Some children first encounter this dominant language in kindergarten. Hearing, language comprehension, speech recognition and language development are therefore crucial.

Children with permanently impaired hearing need an especially good acoustic environment. Donaldson's College for the Deaf, in Edinburgh, Scotland, recently constructed a new building that included a kindergarten section for young children with partly or totally impaired hearing. The rooms are designed for small groups and are well laid out with ample daylight, suspended acoustic ceilings and sound-absorbing panels on the upper sections of the walls have been used to control the acoustics of the rooms (Chapter 5).

Special consideration should be given to children or students with impaired vision, for whom listening skills are prime means of communication with the external environment, including people. The capacity of blind and visually impaired people to perceive sources of noise and the distance to noise sources gives important acoustic information. Every acoustic barrier such as high noise levels or inadequate reverberation time are barriers for hearing, understanding, communication and orientation for blind people. A good acoustic environment is very important, as is how the teachers or presenters speak. They should learn to speak slowly and take the acoustic climate into account.

4.6. Preventing noise in day-care settings

4.6.1. Environmental noise

Health effects of noise on children and perception of the risk of noise (14) collected and presented various examples of sources and levels of noise. This section describes measures to prevent or reduce the noise that can adversely affect young children. Chapter 5 describes in great detail technical measures in schools that are also relevant to day-care centres.

Noise from rail, road and air traffic as well as from industry and other commercial, social and leisure activities constitute the environmental noise for day-care centres. Environmental noise should be minimised or avoided, and taking action at the planning stage is imperative. Controlling or reducing environmental noise is extremely difficult once the day-care centre has been established. The sources and levels of background noise must be considered in locating the centre. Noise control measures can be very expensive and not too successful; this depends on the type of building in which the centre is located.

Centres may be located close to one or more or even all of these sources of environmental noise. Outdoor areas such as gardens and playgrounds and areas where children sleep outdoors are also affected by noise.

The city of Modena, Italy has given noise mapping high priority and developed a good system. The first noise map in Modena was prepared in 1988. The Framework Law on Noise Pollution (9) states that local authorities must develop noise plans. Modena was the first municipality in Italy to prepare a noise-abatement plan, and the municipal council adopted the plan in February 1999. The plan is an action plan to combat noise and specifies that private and public developers are responsible for preparing a project that respects the targets of the noise plan. Based on the actual noise conditions at the development site, the developer must make it plausible that the noise limit values will be respected. For a residential area, for example, the cost of the noise barriers necessary to protect the houses from environmental noise will be part of the development plan and the costs of the noise abatement will be included in the property. After construction, the municipality ensures that the noise level does not exceed the planned maximum.

Soft porous road surfaces can reduce traffic noise by up to 9 dB (15). Quieter cars, speed limits, road bumps and special types of tyres can all reduce traffic noise. It is beyond the scope of this report to go into detail about the technical requirements of road surfaces, speed limits, cars and tyres in noise reduction, but giving priority to the planned use of these measures can help specific day-care centres.

Noise barriers can be built between a day-care centre and a busy road or railway, or traffic can be regulated to other routes or led through a tunnel. The effects of opening a tunnel can dramatically affect people. The Lundby tunnel in Sweden directed traffic away from a residential street. The tunnel was established in a residential area exposed to traffic noise. The noise level outside the houses beside the roads has decreased by 9–14 dB (16). Although this example does not relate to day-care centres, the situation is relevant to day-care centres.

Day-care centres are often allowed in all kinds of planning zones. For example, in Germany the maximum noise levels accepted in kindergartens can vary according to the general noise rules for that area.

Buildings with day-care centres located in noisy environments should comply with specific insulation values for building components such as provided for by a presidential decree in Italy (see section 4.4.3) (11). Windows may need to be specially designed with several layers of glass, and other parts of the building should be carefully designed, such as the roof and building partitions.

The quality of materials and construction work are important in preventing environmental noise from influencing the indoor environment. Environmental noise may still lead to problems indoors when rooms are naturally ventilated by opening windows. Mechanical ventilation can be seen as a way of avoiding the need to open windows that face noise sources, but the ventilation system must be carefully designed to avoid internal noise and it must be maintained regularly to keep it efficient and to avoid hygienic problems. Besides, air taken in through open windows often feels fresher and allows the potential pleasant sounds of birds and playing children and pleasant smells from trees and flowers to enter.

4.6.2. Playgrounds

Playgrounds at day-care centres can be adversely affected by environmental noise. Nevertheless, playgrounds can play a role for coping with noise inside a centre. Many children who make excessive noise indoors find ways to play creatively outside, thus not disturbing the other children who are inside (17).

Cultures differ in attitudes towards the role of the outdoors and of the perception of the health and social benefits of children playing outside. The space available outdoors and whether this space is quiet or exposed to environmental noise can influence crowding and the educational opportunities for using the outdoor areas for playgrounds, physical exercise, gardening and children’s naps. Outdoor areas can be used all year around, whether in sun or snow.

The noise levels outside many centres exceed 55 dB(A), which is a guideline for when noise is considered to adversely affect health. This is important in deciding where to use funds for reducing noise. Many methods of reducing the noise level outside or inside buildings can be expensive, and many techniques may not be able to be used, such as noise barriers. Each case should be assessed on its own merits depending on the noise source and the location and type of building.

4.6.3. Preventing noise outdoors

Planning for the design and location of day-care centres should consider how to avoid environmental noise. Avoiding noise from transport or industry must be balanced with establishing the centre where it is needed. The quality of the day-care centre is reduced if noise prevents the outdoor space from being used optimally.

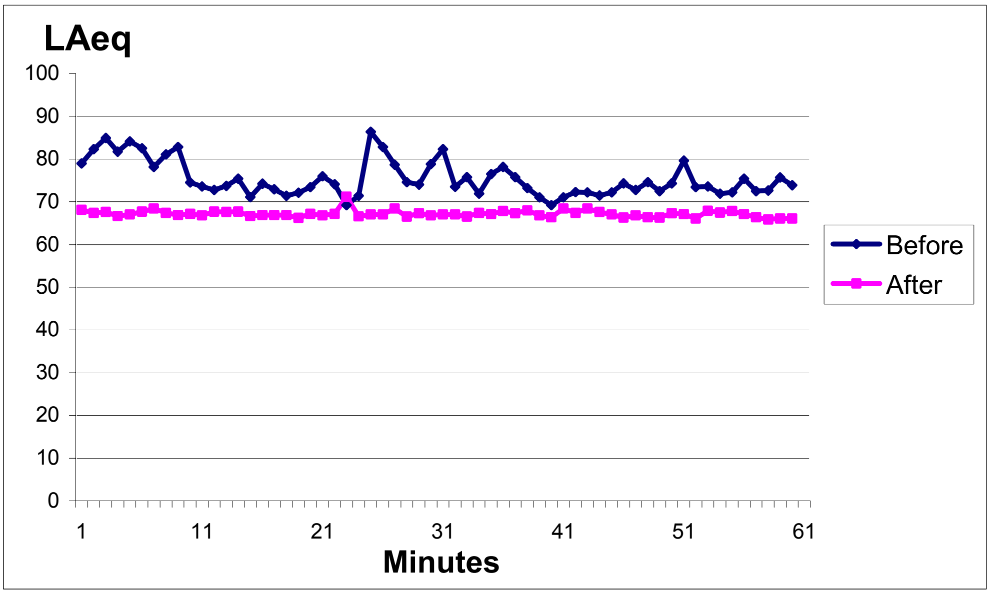
Denmark. Løvegården is a kindergarten located close to Copenhagen Airport. Parents complained about the noise levels and were concerned that the noise would harm their children's development. The municipality decided to take the children out of the building and locate them in other buildings, while investigations determined whether the buildings were suitable for day-care purposes. The medical officer of health stated that the municipality should not use these buildings for day care for young children. The medical officer of health especially noted that the general noise burden and noise peaks outdoors were unacceptably high (section 4.11.2).

Italy. Noise from the Malpensa Airport in Milan adversely affected several kindergartens and schools near the airport. A thorough study of each of the buildings has led to a plan for intervention for each centre. Noise control measures include insulating roofs and walls and inserting new windows with excellent sound insulation (section 4.11.3).

Melita is a kindergarten in Greater Copenhagen located at the intersection of two major streets regulated by traffic lights. During an ordinary week, road traffic creates continuously high noise levels. Variation in the noise levels reflects vehicles stopping and starting because of the traffic lights, interspersed with the occasional but almost daily passing of emergency vehicles with sirens.

The noise level at the building façade was measured at 77 dB(A), and the former noise-screen was not tall or sturdy enough to reduce the noise level. According to the director of the kindergarten, quieter activities such as reading could occur in only one tiny spot behind a shed. The municipality decided to build a new noise screen. Figure 4.1. illustrates the improved situation after the noise screen was built.

Figure 4.1. Noise levels at Melita Kindergarten, Copenhagen, Denmark before and after a noise screen was built



Before the new screen was constructed, the children were asked about their perception of the noise in the playground. They said unanimously that the worst noise in the playground was the noise from cars and from children screaming and yelling. Once a week the children visit a section of the kindergarten that is located in the forest. The children then cherish the sound of birds, animals and the wind and the sounds of the other children.

4.6.4. Internal noise

The noise experienced indoors consists of the environmental background noise and the noise from installations and from human activities.

Internal noise. Internal noise is the noise existing in rooms with human activities and with the noise from functions such as ventilators, exhaust fans, pipes, installations and household supplies. Internal noise also includes the acoustic qualities of outside and inside walls, doors leading outside and doors between rooms and the character and quality of floors, walls and ceilings and the furniture, toys and other equipment in the rooms.

Space and crowding. A very general observation and experience is that crowding of children creates noise. Too many children in too little space not only increases the risk of spreading infectious diseases but also the noise level, which may lead to stress and perhaps aggressive behaviour. Staff in day-care centres have advised for years against placing too many children in small rooms; reducing the number of children per square metre or increasing the number of square metres per child reduces both noise and the burden of infectious disease (18). Reducing the number of children in each group or in the centre as a whole helps to avoid crowding.

More children are often enrolled in a day-care centre than the number for which it was designed; the crowded situation leads to children often wanting to play in “non-designated areas” such as hallways, closets and offices. Regulations on reverberation time do not apply to these rooms, however, which may result in a harmful noise environment (19).

The space requirements for new day-care centres built since 1995 in Denmark have been 2 m^2 of floor space per child in kindergartens (children 3–6 years of age) and 3 m^2 in day nurseries (0–3 years of age) (6). The space allowance does not include kitchens, bathrooms and hallways. Cities such as Copenhagen have a few day-care centres without outdoor playgrounds.

Day-care inspection, UK. The day-care inspectors use their common sense when assessing noise. Most noise comes from the staff playing the radio loudly or from a noisy ventilation system. If the inspector finds it difficult to hear what the children are saying then the noise level is too high, depending on the length of time of the noise. Music may be good, for example during art classes or projects, if it is not too loud. Some child-minders have the television on most of the day. The inspectors may ask about how much the television is used (interview, Maggie Thorpe).

Less than 20% of inspections note that noise is a problem, and noise is usually considered a minor problem. Less than 5–10% of the inspections will require, for example, that the radio be turned down. The inspector can (but rarely does) ask an acoustic technician to measure noise in a day-care centre. An environmental health officer is more likely to do this.

In England, the Office for Standards in Education (OFSTED) inspects day-care centres (and schools) and produces a publicly available report (20). Table 4.1 includes day-care centres selected randomly from numerous reports discussing noise problems.

Noise from adults. The role of adult staff in day care is to take care of and tend to the children as well as to organise daily life. The children generally view adult behaviour as an example of how to behave. If adults raise their voices to be heard, then the children may perceive this as normal behaviour. Adults may slam doors, speak loudly on the phone or play the radio loudly or they may speak quietly and focused, thus setting examples, good or bad, for the children.

Table 4.1. Typical acoustic problems in nursery education premises in England extracted from OFSTED reports

Nursery name	Dates of inspection	Comments on acoustics
Belmont Day Nursery, Chesterfield, Derbyshire	7 March 2001	"However, noise levels sometimes affect the quality of teaching during activities which need a greater degree of concentration."
Lynwood Nursery, 40 Sinclair Avenue, Prescot, Merseyside,	26 March 1997	"However, when it is difficult to hear the performing child above the background noise the value of the activity is lost and, consequently, the efforts of the children can appear to them to be undervalued."
Thomas Spencer Day Nursery, Grand Deport Road, Woolwich, London	9 December 1999	"Children demonstrate an enthusiasm for books, to which staff respond well. However, the quality of the activities can be inhibited by noise levels, which affects children's listening skills and their enthusiasm for stories."
Flintstone Playgroup, the Flintstone Centre, East Street, Littlehampton, West Sussex	13–14 July 1998	"Noise levels are high and not effectively monitored, making it very difficult for children to concentrate and persevere."
Woodside Playgroup, T.S. Vanguard Hall, 9A Broadwater Road, Worthing, West Sussex	2–3 February 1999	"Staff form a cheerful, hardworking team, and they are generally deployed well, although the noise of furniture being cleared away mid-morning can make it difficult for children to hear the adult taking them for 'register'."
Bright Stars Nursery, 221 Lea Bridge Road, Leyton, London	14 December 1999	"Staff use activities well throughout the day to promote good speaking and listening skills although the noise level in the building can make this difficult."

Source: Office for Standards in Education (20)

Noise from children. Children act in the environments adults make available for them. Children play with toys, some quiet and some noisy; they play alone and in small groups and are quiet or vocal. In rooms with background noise, children tend to talk loudly to be heard or may even scream, thus potentially harm their hearing and that of other children as well as their own voice, which may lead to hoarseness and vocal nodules.

4.6.5. Preventing indoor noise in day-care centres

It is important that the external walls, windows and roofs of the buildings housing day-care centres be capable of preventing environmental noise from entering the indoor areas and thus increasing the background noise level. The following sections describe the results of various intervention measures primarily indoors in the day-care centres. The information has been collected by interviewing key people and from material distributed by these people.

Project Being Heard (Ørenlyd). In Roskilde County, Denmark a project was initiated to reduce noise in day-care settings. Forty day-care centres with 2400 preschool children and 385 staff in several municipalities participated: 50% of the children in preschool day care in Roskilde County.

The interventions are broad in scope, including technical measures such as acoustic treatment, reducing the noise caused by furniture, toys and other equipment, interior decoration and use of rooms as well as educational and organisational changes.

The technical interventions included using room dividers to divide larger rooms into smaller areas. The room dividers could be furniture such as bookcases, movable walls or pinboards on legs. The organisational changes included allocating children into smaller groups, establishing new routines and habits around meals and increasing the use of the outdoor space.

Noise measurement was used as an educational tool and to monitor the effects of the technical interventions. The monitoring has shown the effects of the intervention on the noise level and reverberation time, and measurements after the intervention indicate that the average noise level has been reduced by 4 dB, equivalent to more than halving the noise level (interview, Flemming Serup) (see section 4.11.1 for more detail, including a table with the interventions and the sites).

A kindergarten in Germany. The parents of the children at a relatively new kindergarten in northern Germany complained to the director that their children were suffering from frequent headaches. The noise levels and reverberation time were measured in the rooms in which the problem of noise was considered greatest. The reverberation time in the hall was 1.22 seconds and 0.9 seconds in the group room (versus the 0.6–0.7 seconds recommended in Germany for educational rooms). Noise was measured in the hall during a lunch break; the average sound level (L_{eq}) was 81 dB(A), and peaks exceeded 100 dB(A).

In the hall, the existing sound-absorbing tiles comprising lightweight wood panels were removed, because the sound-absorbing material was not effective and not of good quality. Instead new lightweight mineral sound-absorbing tiles were mounted on the whole ceiling. In the adjacent room, existing acoustic tiles covering just the middle of the ceiling were kept, and new lightweight mineral acoustic tiles were mounted, so that the whole ceiling was covered.

Once the work was completed, the reverberation time declined dramatically to 0.8 seconds in the hall and 0.6 seconds in the group room. In the absence of acoustic guidelines for day-care centres, the guidelines for classrooms were applied, since children in kindergarten depend on speech intelligibility, as do schoolchildren. The German standard, DIN 18041 (21), suggests a reverberation time of between 0.6 and 0.7 seconds for ordinary classrooms: the group room is now within this range and the hall slightly higher. Fig. 4.2 and 4.3 in section 4.11.4 show the noise levels before and after the intervention.

The sound was expected to be reduced by about 2 dB, but measurements showed a reduction of 4 dB, which is noticable. (A reduction of 10 dB is experienced as less than half the previous noise level). The interviewee indicated that this is not a special case: acoustic negligence is experienced in many other day-care centres and schools in the area (section 4.11.4) (interview, Carsten Ruhe).

Sound levels and reverberation time in primary schools in Germany are regulated based on speech intelligibility. There are no special regulations for noise in kindergartens, and the regulations applying to the residential area in which the kindergarten is located usually therefore apply. It could be argued, however, that because language development is crucial for young children, the lower noise levels applying to schools should also apply to kindergartens.

Music, radio and television in day-care centres. The organisation of inspection of day-care centres and the role of local authorities are in a transitional period in England. Neither the old national standards from the Department for Education and Employment nor the new ones from the Department for Education and Skills mention the maximum or acceptable levels of noise. Surprisingly, day-care staff seldom complain about noise in these day-care centres.

4.6.6. Day-care centres for schoolchildren

We have found few examples of noise prevention measures in after-school and at-school care for schoolchildren. In fact, there have been complaints that some centres established for schoolchildren for after-school care are not regulated at all, either space requirements or noise and reverberation time.

*Denmark – after-school care***.** Søslangen, an after-school care facility in Søborg, Denmark, is located at a primary and lower secondary school in rooms that have 72 m^2 of floor space and were previously used for teaching. The staff at Søslangen has experienced noise as a problem, and a process for developing an action plan was initiated. The staff and children produced the following action plan:

Objective

- To reduce noise

Methods

- Use and furnish rooms in a flexible way (room dividers)
- Place felt pads on legs of chairs and tables
- Conduct a workshop on noise
- Measure the levels of noise
- Be aware of the noise factor when preparing work plans

Criteria for success

- Reduction of noise and of stress

According to Søslangen's director, achieving these objectives will be a long-term priority, because some of the activities require time and resources. The educational activities are the most cost-effective and are also often effective in reducing noise. The most effective noise-reducing measure is to avoid crowding in the rooms. This can be done by using the outdoor areas, going on trips with smaller or bigger groups or playing at the playground.

Because the rooms are few and large, all children's activities take place in these rooms. It is therefore important to subdivide the room into smaller areas, to create quiet areas that appeal to quiet play. In order to achieve flexibility in the use of the rooms, bookcases are equipped with wheels so they can be moved around, but they still need to be stable. Some chairs and tables are equipped with felt pads, but more still need to be equipped.

The escape route has a stone floor, and this is a hard surface that reflects noise and contributes to a long reverberation time (interview, Lars Priergaard).

4.7. Other preventive measures in day-care settings

This section gives an overview of the organisational and educational measures that have been implemented in day-care centres.

4.7.1. Noise during meals

Meals within day-care centres are often a noisy activity, but less noise can be achieved if:

- Children eat when they are hungry and not when it is expected;
- Children eat in smaller groups instead of everybody at the same time;
- Tables are covered with a thick oil tablecloth;
- Plastic dishes and cups are used; and
- The radio is turned off.

4.7.2. Organisational measures

Organising children in smaller groups and according to their preferred activities can help children who need to concentrate to find more peaceful places in day-care centres (22).

4.7.3. Noise from toys

Some toys that are legally produced and sold, such as powdered toy guns that use percussion caps to create a bang, can create peak noise up to 140 dB (14). Even if they are not common in kindergartens, they serve as examples of how dangerous noisy toys can be. Staff in day-care centres should test the noise level of existing toys and get rid of noisy ones. Staff as well as parents should test the noise level of toys before buying them or making them available.

Staff in day-care centres can place thick and loose but sturdy and washable mats or carpets on the floor or thick and washable tablecloths on the tables where children play with noisy toys, such as building blocks and slot car tracks. Toys can be placed in soft baskets made of willow or plastic rather than in boxes of hard material such as wood or metal.

4.7.4. Hygiene and the use of sound-absorbing material

Potential conflicting interests exist between preventing noise and hygienic requirements for the use of carpets, tablecloths and curtains in day-care centres. Dust, dampness and house-dust mites may be hazardous to children and adults with allergies and asthma.

Denmark. When the health risks of inhaling asbestos fibres came into focus and the role of carpets in holding onto dampness and harbouring among other potentially hazardous factors, house-dust mites and fibres became apparent in the 1980s, large-scale renovation was initiated in Denmark. Sound-absorbing tiles containing asbestos fibres and wall-to-wall carpeting were removed. Legislation was adopted prohibiting carpets in day-care centres and schools.

In 1986, engineers warned that older day-care centres should not be renovated at the expense of acoustic requirements (23). The Danish Building Regulations (6) stipulate an average reverberation time in the frequency range of 125 to 2000 Hz of 0.6 seconds or less. The average reverberation time measured in ten day-care centres before the renovation was between 0.13 and 0.54 seconds in this frequency range. Thus, all these older centres complied with the requirements for reverberation time. The good acoustic climate in many day-care centres was attributable to acoustic ceiling tiles and textile floors, and Lundqvist et al. (23) were concerned that the acoustic climate could decline if these sound-absorbing materials were removed.

Sweden. The Swedish Association of Hard of Hearing People and Swedish Asthma and Allergy Association responded to the conflicts about the effects of flooring material and initiated a collaborative effort to find good material that could be used to improve the acoustic climate and to comply with indoor climate requirements for people with asthma and allergy (24).

4.8. Raising awareness

Preventing noise in day-care settings can be addressed as a general public health campaign or be targeted for specific age groups or professional groups. Preparing a picture book with rhymes for children is a way of addressing the child. Another example is the use of video and television programmes highlighting the nature of dangerous noise from toys or the effect of noise on human hearing.

4.8.1. Behaviour modification

Behaviour modification can target either adults or children, but successful behaviour modification among children is more likely to succeed if the adults around them serve as role models.

United Kingdom. Meg Bender of the Preschool Learning Alliance, which operates in the United Kingdom, estimates that about 50% of the day-care centres included in the Alliance suffer from noise problems. One reason is an inadequate physical environment, with excessively high ceilings, lack of sound insulation and absorption, lack of curtains, tiles on floors instead of carpeting and other factors. Another reason is that many day-care centres do not own the premises in which care takes place and therefore do not sufficiently control the physical environment. Traffic noise is a problem, as is sound from radios, tape recorders, televisions or videos. Music becomes a source of continuous background noise upon which children and staff have to communicate. The noise from children and staff is the most serious; it may not be easy to address but is relatively inexpensive.

Many problems may be addressed through dialogue and discussions about behaviour modification. The Preschool Learning Alliance uses an awareness-raising approach and addresses noise and behaviour modification at courses for staff or through the development workers that regularly visit the day-care centres. Behaviour modification among staff could include stopping shouting across rooms to get children's attention. Parents need to be included to discuss the role of adult behaviour. Good practices are generally needed (interview, Meg Bender).

4.8.2. A video and public announcement

Sweden. The Stockholm Association of Hard of Hearing People has produced a video about the noise level of toys and the associated hazards (see example of good practice in section 7.9.3.) (25).

4.8.3. Use of a graphic noise-measuring device in Denmark and Sweden

Some kindergartens have introduced the use of a graphic noise-measuring device designed as a large ear and equipped with a red and a green light. The device is adjusted to react to a certain sound level: if the noise in the room stays below the set maximum, the green button stays lit. If the noise level exceeds, for example, 90 dB(A), the red light is visible, or the ear turns red. The children and adults can monitor how much noise they create by watching the colours. An estimated 4000 of these devices were sold in Denmark, Norway and Sweden from 1999 to 2001.

Denmark. Politicians responsible for day care in a municipality in Greater Copenhagen decided to approach the problem of noise in day-care centres by buying 25 of the noise-measuring devices that are lent to centres for a period of time. Some kindergartens are pleased with the device; others are interested in the beginning but later ignore it. Children might inadvertently or deliberately make noise so that the red light goes on.

The use of the noise-measuring device has not yet been evaluated, which only allows some general impressions. The centres included in Project Being Heard said that educational activities related to the device are the decisive factors for its use. If the device is being used based on an understanding among staff and children of what produces noise and the effects this noise has, the device can be said to have a positive effect. A behaviouristic response, such as staff saying to children that "the device is red, please be quiet", does not develop the understanding and control of the mechanisms producing noise, but just leaves children with a feeling of guilt for having again turned the device red (interview, Flemming Serup).

4.9. Other prerequisites for preventing noise in day-care settings

4.9.1. The role of education and training

Noise is often forgotten when environmental protection is discussed but also seems to be lacking in the training of architects and engineers. The role of acoustics needs to be upgraded in the current education and in planning and building day-care centres. In addition, the staff need training in and understanding of noise and preventing noise. Guidelines on organisational, technical and educational approaches can help staff members (17, 19, 22, 26, 27).

4.9.2. The views of parents

Denmark. The Danish Federation of Early Childhood Teachers and Youth Educators and Danish Union of Nursery and Childcare Assistants conducted an interview survey of 1011 parents with children in day-care centres, including day nurseries, kindergartens, age-integrated centres, after-school centres and after-school activities at school (28). The parents were generally pleased with the day-care centres, but the satisfaction waned in response to more specific aspects. The parents are least satisfied with the indoor environment, the lack of space and the level of noise in their children's day-care setting. Of all the questions asked, parental satisfaction was lowest for these three parameters.

4.10. Conclusions on preventing noise in day-care settings

Acceptable levels of environmental and internal noise as well as a good acoustic climate are crucial in preventing any negative effects of noise on children. Awareness, political will and legislation are also prerequisites for obtaining environments that are acoustically good, comfortable and support children's development. Important factors include training staff and discussing with children about the difference between noise and sounds; training of skills to identify annoying noise; and trying to abate noise. This chapter and the following examples of good practices serve as documented examples of the benefits of organisational and educational changes in daily life in day-care settings and of technical and acoustic interventions.

4.11. Examples of good practices

This section describes in detail the organisation, experience and evaluation of four examples identified by interviews that were chosen as good practice in day-care centres:

- Measures to prevent noise and its effects in day-care centres in a county in Denmark;
- The role of a medical officer of health in dealing with noise at a kindergarten near an airport – Løvegården;
- Preventing noise in day-care centres and schools around Malpensa International Airport in Milan, Italy; and
- Effects of improving the reverberation time in a kindergarten in Germany

4.11.1. Measures to prevent noise and its effects in day-care centres in a county in Denmark

The preventive measure
Project Being Heard (Ørenlyd) comprises organisational, technical and educational measures to reduce or prevent noise in day-care centres in Roskilde County, Denmark.

Characteristics and magnitude of the problem to be prevented
The project addressed all kinds and sources of noise in day-care centres, primarily kindergartens (with children aged 3–6 years). The type and seriousness of the problem thus varied across centres, but are symptomatic of the general noise problems in day care.

The target population
Staff and children in day-care centres for preschool children. Numerous administrative personnel in municipalities were involved in training and in developing the project.

The setting
Day-care centres for preschool children in several municipalities in Roskilde County. Altogether 40 centres participated, involving 2400 children and 385 staff. This amounts to 50% of the children in preschool day care in Roskilde County.

Description
The first step was educating the staff in day care. A training course was developed and staff was introduced to concepts and mechanisms of noise, acoustics and the physical environment. Based on this new information and their existing knowledge and experience with child development, the physical situation of their centre and the organisation of daily activities, staff established new practices aimed at reducing noise.

The interventions are broad, in the sense that they include technical, material activities such as acoustic treatment, noise reduction of furniture, equipment and toys, interior decoration and use of rooms as well as educational and organisational changes.

The technical interventions consisted of using room dividers to subdivide larger rooms into smaller areas. The room dividers cold be furniture, movable walls or pinboards on legs.

The organisational changes consisted of dividing children into smaller groups, establishing new routines and habits around meals and using the outdoors more. Table 4.2 shows the interventions and the location of the interventions.

Documentation of effect
Based on the noise measurement, an overview is achieved of noisy activities during the day, thus identifying the areas for intervention. Noise levels can be monitored to assess the effectiveness of the interventions. The measurements of noise may not be exact, because it takes many measurements to determine the exact noise load during a day. Measurements of reverberation time and of noise peaks are exact.

Measurement after implementation indicates that the noise has been reduced by 4 dB on average, which is noticeable.

Noise measurement is used to monitor the effects of the technical interventions and as an educational tool. The monitoring shows the effects of the intervention on the level of noise and reverberation time.

Positive side effects
The interventions have reduced noise in the participating centres and have, in addition, increased the educational awareness and in several instances changed educational and organisational practises.

Organisation
Several municipalities in Roskilde County in cooperation with an occupational health consultant carried out the project during a period of 2 years.

Economic analysis
Approximate costs, including noise measurement, education of staff in the centres and technical improvements, amounts to EUR 54,000. Relative to the reduced risk for children and adults and the higher educational awareness, this is a very small amount.

Ethical perspectives
Staff, parents and children enthusiastically accepted the project. Employers and some trade unions needed more time and explanations to accept the project.

Table 4.2 Interventions and location of intervention based on experience from Project Being Heard

Place or activity	Regulations	Barriers to transmission	Information	Other kinds of measures
a. Children's activities indoors	Subdivision of rooms Subdivision of children into smaller groups	Smaller or more rooms Furniture Room dividers Acoustic regulation	Visualisation of the noise Noise measurements	Soft surfaces Felt-pads on furniture Thick vinyl-covered tablecloths
b. Adults' (personnel, parents) activities indoors	Modified educational principles Innovative organisation of activities	Children have less waiting periods Increased concentration	Debates about educational tools Insights about noise	Education Projects about noise
c. Installations in the day-care centre	Noise standards for equipment and machines	Physical location Special rooms Insulation and encapsulating	Legislation Information	
d. Children's toys	Discarding noise toys Common European Union regulations on noise insufficient Establishing noisy and quiet sections	Soft washable carpets Baskets and boxes of soft materials (willow, plastic)	Meetings with parents Public debates	
e. Road traffic in the surroundings of the day-care centre	Legislation and standards on noise emission and zoning Ministry of the Environment	Physical location of day-care centres Distance Noise walls		
f. Railways in the surroundings of the day-care centre	Legislation and standards on noise emission Ministry of the Environment	Physical location of centres Distance Noise walls		
g. Air traffic in the surroundings of the day-care centre	Legislation and standards on noise emission Ministry of the Environment	Physical location of centres Distance Noise walls		

Source: Flemming Serup

Barriers

Employers were afraid of costs and the risk of being accused of fostering a poor working environment in their day-care centres. The trade unions were afraid of compromising their demand for more space in the centres.

The existing documentation

Experience from this large project and a few other similar projects has been collected and published (17, 19, 22, 26, 27).

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The review is based on an interview with Flemming Serup on 9 April 2001 in Copenhagen, Denmark.

4.11.2. The role of a medical officer of health in dealing with noise at a kindergarten near an airport – Løvegården

The preventive measure
The medical officer of health advised the municipality to not reuse a building for day-care purposes. Children in a kindergarten, Løvegården, were removed from Løvegården because they were exposed to noise from airplanes operating at Runway 04 at Copenhagen Airport.

The medical officer of health concluded in his communication with the municipality that he could not recommend that the municipality again offer day care for young children in the same buildings and surroundings. It is especially noted that the average and peak noise levels in the garden is unacceptable and that the peak noise levels in the yard are also unacceptable.

Based on noise measurement, the available scientific literature and the recommendations of the World Health Organization, especially for day-care centres, the noise levels in these buildings and surroundings are unacceptable.

Characteristics and magnitude of the problem to be prevented
The kindergarten is located close to Copenhagen Airport and is exposed to noise from airplanes taking off. A group of parents were concerned that their children were being harmed by the noise and had presented their concerns to the municipal administration.

In 2000, noise was measured inside the kindergarten with and without children and adults present. The noise levels for the measuring period were 78 dB(A) and 81 dB(A). Noise was measured again in 2001 by an acoustic consultant. Table 4.3 shows the results.

In addition, staff complained about noise-related symptoms such as hyperacusis and dizziness, symptoms that had led to sick leave and changes in work functions. In the period before the kindergarten closed, staff took sick leave based on assessment at an occupational health clinic. According to the occupational health clinic, the illness among staff was presented as a chronic stress reaction caused by a combination of aircraft noise and frustrating educational conditions because of the location of the centre.

The medical health officer in the county was involved because the head of the Environmental Department in the municipality requested an opinion as to whether the location of the kindergarten threatens the children's health and well-being. Based on the medical health officers' inspection of the kindergarten he answers the municipality that he assumes that the noise-related symptoms of personnel are applicable to the children and that there is no reason to expect that children are less susceptible to the noise than the adults. The medical health officer indicated that noise measurements were advisable.

Table 4.3. Noise levels measured outside and inside Løvegården Kindergarten in Dragør, Denmark with no children or personnel present, 2001

Measure	**Outside, 10 m above terrain**	**Outside, garden**	**Outside, yard**	**Inside, ground floor**	**Inside, first floor**
$L_{Aeq, 8h}$	72 dB	67 dB	59 dB	38 dB	39 dB
L_{Amax}	96 dB	[88–86 dB]	[88–86 dB]	58 dB	60 dB
L_{pALF}				42 dB	47 dB
L_{pG}				74 dB	71 dB

Source: prepared by the medical officer of health based on measurements by Carl Bro-Acoustica

Information on the uncertainty of the measurements is described in a report from Carl Bro-Acoustica. The measurement was otherwise conducted with windows closed and no children or personnel present.

$L_{Aeq, 8h}$:	Equivalent, continuous A-weighted time-weighted sound pressure level
L_{Amax}:	Peak sound pressure
L_{pALF}:	Sound pressure for low-frequency sound
L_{pG}:	Measured infrasound level

The L_{Amax} values in brackets are estimated values based on measurements of peak sound pressure conducted 10 metres above the surrounding terrain in accordance with an internal memorandum from the Municipality of Dragør of 20 June 2001.

The type and seriousness of the problem
The problem is induced by noise. The medical officer of health stated that the community previously considered noise as a nuisance, but as scientific evidence emerges on the health effects of noise on children, such as increased blood pressure and stress-related diseases and cognitive effects, noise is now increasingly considered a health hazard.

The type and estimated magnitude of the socioeconomic burden
Four staff on sick leave is proof of socioeconomic burden for staff as individuals and for the kindergarten. Parent's collective worries about the potential effects of noise on their children is an emotional burden.

The target population
The immediate target population for the preventive measure from the viewpoint of the medical officer of health was the children at Løvegården. Because children are regarded as susceptible to the noise, children in general are the target group. This is relevant because the municipality has to decide whether the buildings can be used for another type of day-care centre.

The setting
The setting is Løvegården, a kindergarten located next to Runway 04 at Copenhagen Airport. The kindergarten has a yard and a garden and noise is a very great problem outside as well as inside. In addition, low-frequency noise and infranoise is a problem: the walls and windows of the building shake, and the experience when inside can be scary.

Description
The preventive measure consisted of removing the children (and adults) from the kindergarten and placing them in various other kindergartens in the municipality.

The advice by the medical officer of health to the municipality was that the noise levels in the garden and in the yard are causing annoyance to the children. The noise levels probably affect the stress levels of the children and influence their well-being. The noise levels outside risk harming hearing. The medical officer of health says that it is important that the children have access to the outside in relation to day care at the kindergarten.

The centre still exists as a building, and the municipality is considering what to do with the building: whether to reopen it for another group of children or to abandon it permanently for day care purposes.

Documentation of effect
The position of the medical officer of health is based on various recent scientific articles about the auditory and non-auditory effects of noise on children. The group of parents, the acoustic consultants, the municipality and the medical health officer each collected scientific literature and research about the effects of aircraft noise on health to highlight the potential risks to children of exposure to aircraft noise.

When the children were removed from the site they were not exposed to high levels of aircraft noise in day care.

Adverse effects
The children are moved out of their usual environment and risk being separated into different groups at other day-care centres. Children may need stable recognisable surroundings.

Organisation
In Denmark, noise problems of staff are assigned to the working environment service by legislation. Because of lack of legislation about the “occupational” health problems of children, the medical officers of health deal with the noise-related problems of children.

The question of aircraft noise dates back to 1994, when the centre now known as Løvegården was moved to the present building from other premises 600 metres away, because of traffic noise and inadequate buildings. At that time, the National Board of Health advised the municipality that no day-care centre should be placed close to the airport. Nevertheless, the municipality decided to use the present location and pointed to noise limits of 65 dB around the airport and a decision with an exemption in a national planning directive that allowed noise up to 85 dB(A) at night.

The medical officer of health became involved in the case in January 2001 when the municipality asked for the officer’s opinion about the complaints of the groups of parents. The medical officer of health indicated that noise measurements were advisable. After Løvegården started operating, the problems started.

Economic analysis
See comments in the section on barriers.

Ethical perspectives
The parents of the children are the legal representatives of the children. Parents represent important interests and should be accepted as a user group; their concerns should be taken seriously.

Barriers
The medical officer of health experienced no barriers to preparing his position and conclusion.

The municipality had already invested money in the building by applying triple-glazed window glass and by installing a new ventilation system. For the municipality, the investment already made could be seen as a barrier to abandoning the use of the building for day-care centre.

Existing documentation
Studying the effects of noise on children was relatively new in Denmark at the time for all parties involved: the municipality via an acoustic consultant, the parents and the medical officer of health

all studied the recent and relevant literature. Already in 1994, the National Board of Health indicated the problems with noise in the kindergarten and referred to a publication from 1993 by the Danish Environmental Protection Agency, which stated the connection between noise and hypertension, leading to cardio-vascular disease. Also communication problems leading to impaired learning among children were stated.

The review is based on an interview with Arne Scheel Thomsen, 10 October 2001, Copenhagen, Denmark.

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4.11.3. Preventing noise in day-care centres and schools around Malpensa International Airport in Milan, Italy

The preventive measure
A variety of preventive measures were implemented in six nurseries, five primary schools, one secondary school and one centre for people with handicaps, altogether 13 centres, around the Malpensa Airport.

Characteristics and magnitude of the problem to be prevented
The schools and day-care centres were affected by noise passing through windows, roofs and walls. An estimate is that most nurseries, primary and secondary schools in the area were affected by the noise from the airport. The estimate is based on knowledge about the age of the schools and of the character of construction and the level of maintenance.

The target population
All child ages are represented in this example, and age group 16-35 for one institution.

The setting and background
Malpensa was a small airport and in the last years became a hub. The growth of the traffic of the airport and the development of the hub started when international flights moved from Linate to Malpensa in recent years.

The noise problems from the flight area of Malpensa Airport affect many municipalities around the airport. The noise situation became a political issue, and all sectors were involved in addressing the problems: from inhabitants, municipalities, airport authorities, the regions, and different ministries such as the ministers for health and environment, for public works and for industry.

The national government and the Lombardia Region provided funds with the aim of changing the flight patterns and to improve the acoustic insulation in buildings located near the airport. A contract between the Lombardia Region and the Central Institute of Building Industrialization and Technology (ICITE) of the National Research Council was entered to develop the necessary background documentation and technical proposals and specifications for the acoustic improvements.

The municipalities own the nurseries, primary and secondary schools. When the schools were built, there was less noise, when Malpensa was not yet a hub. The main current legislation regarding noise is the Framework Law on Noise Pollution (9), which applies to new buildings. A presidential decree (10) lays down the acceptable levels of noise and noise insulation in schools and day-care centres.

Table 4.4. The building classification and acoustic requirements of buildings in Italy, DPCM 5.12.1997 (11).

DPCM 5.12.2001

TABLE A: BUILDING CLASSIFICATION

- A:	residential buildings or comparable;
- B:	offices or comparable;
- C:	hotels, boarding-houses or comparable;
- D:	hospitals, clinics, nursing-homes or comparable;
- E:	schools of every level or comparable;
- F:	leisure buildings, churches, religious buildings or comparable;
- G:	trade or commercial buildings or comparable.

TABLE B: ACOUSTIC PASSIVE REQUIREMENTS OF BUILDINGS, ELEMENTS AND TECHNOLOGICAL PLANTS

Categories (cfr. table A)	Quantities				
	R'_w (*)	$D_{2m,nT,w}$	$L'_{n,w}$	L_{ASmax}	L_{Aeq}
1. D	55	45	58	35	25
2. A, C	50	40	63	35	35
3. E	50	48	58	35	25
4. B, F, G	50	42	55	35	35

(*): These values refer to separating elements between different dwelling units;
R'_w: Weighted apparent sound reduction index, according to EN ISO 717-1 (unit: dB);
$D_{2m,nT,w}$: Weighted standardized sound level difference of a façade, according to EN ISO 717-1 (unit: dB);
$L'_{n,w}$: Weighted normalized impact sound pressure level in the field, according to EN ISO 717-2 (unit: dB);
L_{Asmax}: Maximum A-weighted sound pressure level with time constant *slow* (unit:dB(A));
L_{Aeq}: Continuos equivalent A-weighted sound pressure level (unit: dB(A)).

Description of the preventive measure

The preventive measures in order of importance:
- Windows and air inlet devices;
- Roofs; and
- Walls.

The main measure used was windows and air inlet devises. The intervention consisted of replacing existing windows with new ones with excellent sound-insulating performance.

ICITE's task was to solve the problems for some schools and day-care centres selected by the Region, and the aim was to solve noise problems with different techniques applied to different buildings with different problems.

The experiment was to improve the buildings with different measures; some schools are near the airport and some further away. The size of the interventions was a large experiment that led to considerable experience with different kinds of measures that could serve as examples of good practice.

ICITE performed very strict building analysis of the selected day-care centre:
- Technical solutions: windows, roofs and walls;
- Types and size of windows;
- Characteristics: technical aspects, presence of insulation;
- Size and materials; and
- Conditions, such as maintenance.

Field measurements of noise insulation were carried out in selected rooms for each building.

Technical solutions were designed based on these building and noise analyses, and all quantities and dimensions and sizes was determined for each school for each floor. The result was very detailed instructions on which kind of roofs, walls and windows were to be used at each school, including details important in achieving the technical performance desired. Examples include the right documents regarding the properties of the elements to be added by the firm or the technical characteristics, such as the sound insulation performance of windows, thermal properties, closing and opening systems and airtightness. The requirements for the contractor were very strict and detailed to guarantee a high level of quality in implementation.

One of the side effects was the exchange of air inside the rooms. Allowing the right amount of air to pass required including some air inlet devices, such as mechanical ventilation elements with a high noise insulation capacity. The ventilation systems were tested for air exchange and for noise.

The main interventions were to improve the sound insulating qualities of façades and roofs. Other measures were installation of sound-absorbing material in a hall in one of the schools.

Table 4.5 shows the insulation capacity in dB of the facades for the rooms measured in each day-care centre. The range of weighted apparent sound reduction index values (R'_W) for walls with windows before the interventions was 19–38 dB.

Summary: final evaluation starting from ICITE's in situ measurements on walls with windows before and after the intervention.
- DnT,w: weighted standardised sound level difference (unit: dB);
- C: pink noise adaptation term, according to EN ISO 717-1 (unit: dB);
- Ctr: traffic noise adaptation term, according to EN ISO 717-1 (unit: dB);
- ∆ DnT,w: sound insulation improvement (unit: dB).

Table 4.5 Range of weighted apparent sound reduction index values (R'$_W$) for walls with windows in rooms in day-care centres before and after intervention

					before			after			improvement
ID[1]	School	Room[2]	Volume[3]	Surface	$D_{nT,w}$	C	C_{tr}	$D_{nT,w}$	C	C_{tr}	□$D_{nT,w}$
1	Maddalena							**2001**			
		1	159,484	30,91	28	-1	-2	**46**	**-2**	**-5**	**18**
2	Ginelli							**2001**			
		1	140,32	23,21	26	-1	-2	**45**	**-1**	**-4**	**19**
3	Baracca										
		1	149,36	32,19	26	0	-2	**41**	**-1**	**-5**	**15**
		2	122,86	24,72	27	-1	-2				
4	Fermi										
		1	133,3	22,40				**41**	**0**	**-4**	
		2	156,352	24,43	26	-1	-3	**45**	**0**	**-5**	**19**
5	Coarezza							**2001**			
		1	114,712	19,78	34	-1	-4	**45**	**-1**	**-5**	**11**
5 bis	Rodari							**2001**			
		2	155,88	23,06	28	-1	-2	**43**	**-1**	**-4**	**15**
		3	212,23	22,94	19	0	-1	**43**	**-1**	**-3**	**24**
6	Perograno										
		office						**37**	**-2**	**-5**	
		1			22	0	-2	**35**	**-1**	**-2**	**13**
7	Sormani										
		3	113,62	16,35	31	-1	-2	**45**	**0**	**-3**	**14**
8	Ferno										
		1	117,705	19,95	29	-1	-3				
		5	147,0					**39**	**-1**	**-2**	
		2	193,905	27,90	33	-2	-4	**40**	**-2**	**-2**	**7**
		16/17	387,81	55,80				**45**	**-2**	**-4**	
9	Carminati										
		5	187,11	28,35	27	0	-1	**42**	**-1**	**-3**	**15**
10	Dante										
		3	197,786	28,38	38	-1	-4	**46**	**0**	**-3**	**8**
11	Buratti										
		12	200,41	26,27				**36**	**0**	**2**	
		18	47,985	6,65	22	-1	-2				
		25	88,615	18,47	26	-1	-2	**39**	**1**	**-2**	**13**
12	Nido										
		1	56,68	10,95				**37**	**0**	**-4**	
		4	193,85	54,42	26	-1	-1	**47**	**0**	**-5**	**21**

[1] ID: identification number;
[2] room: the code number is referred to ICITE's drawings (i.e.:Maddalena, room 1 is the room with the code 1 in the map);
[3] volume and surface: are referred to the room in which the measurement is made.

Documentation of effect
Starting from the field measurements of the acoustic performances of the selected buildings before the intervention, windows and roofs with better acoustic performances were used in place of the existing ones whenever the latest did not satisfy the sound insulation requirements. In order to satisfy the ventilation requirements, sound-insulated air inlet devices were used. The single number rating of R'_W required for the window was at least 40 dB (in few cases, the project asked for 48 dB).

The range of R'_W values was 35–47 dB after the interventions (Table 4.5).

The improvement in level difference was 8 to 24 dB.

Positive side effects
Reduced heat loss with consequent energy saving
Building rehabilitation
Positive effects on health because of neutralisation of asbestos.

Adverse effects
Overheating during the summertime.

Organisation
In 1999 ICITE contracted with the Lombardy Region Government to organise the prevention of noise in the 13 selected day-care centres. ICITE's tasks were:

- To measure the acoustic performance of the selected buildings before the intervention;
- To project the improvement in sound insulation;
- To give technical assistance to preparing the tender;
- To give technical assistance to the person supervising the work;
- To test in a laboratory some windows and sound-insulated air inlet systems, samples of those that were to be installed;
- To measure the acoustic performance of the selected buildings after the intervention; and
- To draft a handbook on the techniques for improving sound insulation and on the experience gained.

Economic analysis
Cost: about EUR 2,100,000 paid for by the Lombardy Region Government.

Barriers
Fears: no
Costs: very high costs
Risks: no
Others: insufficient technical knowledge among companies submitting tenders.

Existing documentation
This large noise insulation scheme was very successful, and the experience has been used to develop guidelines (29) containing detailed description and documentation of all measures.

The review is based on interviews with Fabio Scamoni and Laura Porro on 22 October 2001 at ICITE.

Links
ICITE
www.icite.mi.cnr.it (both in English and in Italian)
Region
www.regione.lombardia.it (both in English and in Italian)
Aler Varese (on the specific contract (only in Italian)):

www.forumpa.it/forumpa2001/bestpractice/regionando/cdrom/gestioneterritorio/reglombardia/insonorizzazionezonamalpensa.pdf

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4.11.4. Effects of improving the reverberation time in a kindergarten in Germany

The preventive measure
Improvement of the sound reduction in a relatively newly built kindergarten. The reduction took place in a hall that was also used as dining room, and in a randomly selected group room.

Characteristics and size of problem to be prevented
The problem in the rooms was noise due to the too long reverberation time, although noise-absorbing tiles were mounted in the ceiling. The reverberation time in the hall was measured to RT = 1,2 s, and RT = 0,9 s in the group room.

The leader of the kindergarten had received complaints from parents that their children were suffering from frequent headaches.

In absence of guidelines for day care centres (kindergartens) the acoustic guidelines for conference- and classrooms (DIN 18 041, 1968) are suggested with a reverberation time RT between 0,6 and 0,7 s. The interviewee points to the fact, that this kindergarten is not a special case, but that he for the last years has experienced the same acoustic negligence on around 20 newly built kindergartens and schools.

The target population for the preventive measure
The children in the kindergarten were the target group. An estimate is that 70-80% of all children in the age group attend kindergartens for more than 5 hours a day.

The setting for the preventive measure
The place is a kindergarten in the Hamburg area, North Germany. The Hall is built of massive walls and a steel reinforced ceiling. The hall is an irregular shape, 81m2, and 3 metres to the ceiling, and the room volume is 243m3. The floor is covered with linoleum for easy cleaning. In the ceiling 27m² noise-absorbing tiles were mounted.

The adjacent group room is built of steel beams with a suspended gypsum-board-ceiling.
The room is 6m x 8m, and 3 metres to the ceiling, the volume is 144m³. In the middle of the ceiling were 14 m² sound absorbing engineered woodwool-slaps. Because of the small size of the rooms the noise cannot disperse freely, but is reflected by the hard surfaces of floor, walls and ceiling. The low construction height of the room was exasperated by the presence of the sound absorbing mineral wool plates (Schallschluckhinterlegung mit mineralfaserplatten). It was not possible to place e new layer of mineral tiles on top of the old wool plates.

Description of the preventive measure
In the hall the engineered woodwool-slaps were removed and underneath the existing rafters new, interlocking modular mineral lightweight absorptive tiles were mounted. The entire ceiling was adapted with these tiles.

In the group room, the existing wood wool was left and the rest of the ceiling was adapted with the same mineral lightweight absorptive tiles.

Documentation of effect of the preventive measure
Frequency dependant baseline measurements of reverberation time of background noise were taken for the hall and the group room before and after the intervention. The results appear in figure 4.2 and figure 4.3.

Figure 4.2 and 4.3. Frequency-dependent measurements of reverberation time for the hall (4.2) and the group room (4.3) before (A) and after (B) the intervention

Figure 4.2

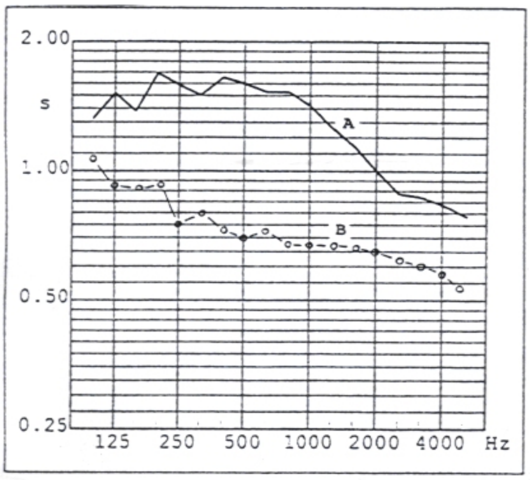
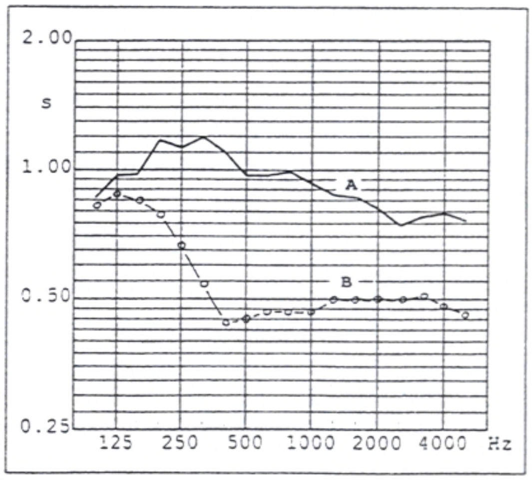


Figure 4.3



In the hall the reverberation time was measured RT = 0,8 s, and in the group room RT = 0,6 s. Noise measurements were taken in the hall during lunch break, with an average sound level of L_{eq} = 81 dB (A). Peaks above 100 dB(A) were measured during the one-hour lunch break. A sound reduction of on average 2 dB was expected after the intervention, but measurements showed a reduction around 4 dB.

Positive side effects of the preventive measure
Before the intervention everybody was complaining about noise especially during singing and eating breaks. After the intervention noise is complained about only during eating breaks.

Research shows that shorter reverberation time in work and communications rooms is beneficial not only for the noise reduction, but also for the language intelligibility.

It is not known whether the cases of headaches in the children disappeared?

Organisation
The leader and the board of the kindergarten initiated the improvement, and the measurements were carried out by the acoustic consultant, including the interviewee.

Ethical perspectives
The ethical dilemma of this intervention is about liability for the poor acoustic qualities in the building, prior to the improvements. The question is whether to call the previous existing and inefficient sound insulation a building error. If this is the case, the consultants (architects/engineers) that designed the kindergarten are liable for legal suits on grounds of neglect. In order to avoid a (collegial) dispute and / or a lawsuit, the intervention was labelled a sound improvement.

Barriers for the preventive measure
It is a barrier that no legislation or guidelines for acceptable noise in day care institution exist. The low room height is a physical barrier to the intervention, as it was not possible to mount hanging tiles to the ceiling and it was difficult to mount lower hanging tiles on the existing ceiling.

The usefulness of the noise measurements would have improved if the sources of noise especially for peaks had been measured, so that attention can be focussed on the causes of noise. The consultants did not measure the source of the noise, but measured the noise for one hour and calculated the average.

About the existing documentation
There is good scientific evidence that reduction of reverberation time can lead to improved acoustic in terms of reduced noise, for example as reduction of noise to speech-ratio.

The review is based on an interview with Dipl.-Ing. Carsten Ruhe, on 18 May 2001 at Taubert und Ruhe, Halstenbek/Hamburg, Germany.

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5. Preventing noise in primary schools

by David J. MacKenzie

5.1. Introduction

As we enter the twenty-first century, one would have thought that the recurring problem of noise in primary school classrooms would be corrected by now. However, this does not seem to be the case based on comments made in recent research papers and reports from school inspectors throughout the United Kingdom. This chapter refers mainly to experience, standards and guidelines from Scotland and England.

Although several important research projects on classroom acoustics have been undertaken, architects and designers of school projects still appear to lack information in their quest to achieve good acoustics throughout the school building. Although many papers concentrate on good classroom acoustics, it is equally important to pay attention to the various other important areas within schools that can influence the overall noise level experienced within teaching spaces. For example, corridor noise can be extremely invasive throughout a school environment.

MacKenzie & Airey (1) have documented well the fact that many schools suffer from poor acoustics in classrooms and other teaching spaces, and this has also been discussed in *Health effects of noise on children and perceptions of the risk of noise* (2).

This chapter examines available information and techniques on how to reduce noise levels within primary schools to acceptable levels. It discusses techniques that have been used in the past and how schools aim to reduce noise levels to diminish distraction among pupils in general. Most comments are based on past experience, especially in undertaking acoustic measurements in schools and classrooms before and then after acoustic treatment has been applied to specific areas within classrooms.

The main reason for this is the tremendous lack of information available on acoustics in educational buildings. Guidelines on environmental design in schools are certainly available in the United Kingdom (3), but practically no information is available on how to achieve these guidelines in practice. No best practice guidelines are available to architects and school designers to assist them in their quest for good classroom acoustics. This report indicates a wide range of effective measures.

5.2. Noise in classrooms – the problem

Children attending primary school in the United Kingdom tend to be located in the same classroom for a particular academic year. For example, year 4 may be located in classroom 4 and will remain there until the end of year 4 studies and then move up to year 5 and use classroom 5. This is different to secondary schools, in which a particular subject is allocated to a classroom and the class visits that classroom to be taught for one or more periods.

Primary school children are therefore more likely to be exposed to classrooms with poor acoustics for a greater length of time. This may be a classroom with a noisy heating system or one that is adjacent to a busy road. One thing is certain: children and often the teachers find themselves in situations in which they can do little to improve the acoustic environment within their classroom.

5.2.1. Previous research project into classroom acoustics

This chapter refers to several research projects undertaken by MacKenzie & Airey at Heriot-Watt University in Edinburgh. Commencing in January 1996, the project lasted for almost 4 years and was split into three phases.

Speech Intelligibility in Primary School Classrooms (1996 to 1998). This project investigated the main causes of poor speech intelligibility within primary school classrooms. A series of objective and subjective acoustic measurements was carried out in everyday classrooms throughout the United Kingdom.

Classroom Acoustics (*1998–1999)*. A series of measurements was made in classrooms before and then after acoustic treatment was applied to the classroom being tested. The treatment was usually either a suspended ceiling or applying acoustic tiles directly to the surface of the existing ceiling. Ceilings were found to be good areas to treat, as they provided a fairly large uninterrupted surface and were not covered with decorative features or posters.

Investigate the Psychological Effect of Excessive Noise on Primary School Teachers (1999). A questionnaire was developed to determine the effect of the internal environment on primary school teachers. Contact was made with head-teachers, school authorities, architects and material suppliers to seek their advice and to ensure that the acoustic measurements were representative of everyday activities in primary schools. An important decision was made to carry out measurements in a range of classrooms, first occupied and then unoccupied. It was important to listen to what the school pupils were experiencing in their classroom environment.

A pilot study into the problem of poor acoustics in primary school classrooms highlighted the problem facing schools worldwide – excessive noise. A series of objective and subjective measurements was made to fully understand the problem of noise. All measurements were carried out in primary school classrooms, mainly on the advice of audiologists at a local hearing assessment centre for schoolchildren in Edinburgh.

5.2.2. Speech intelligibility

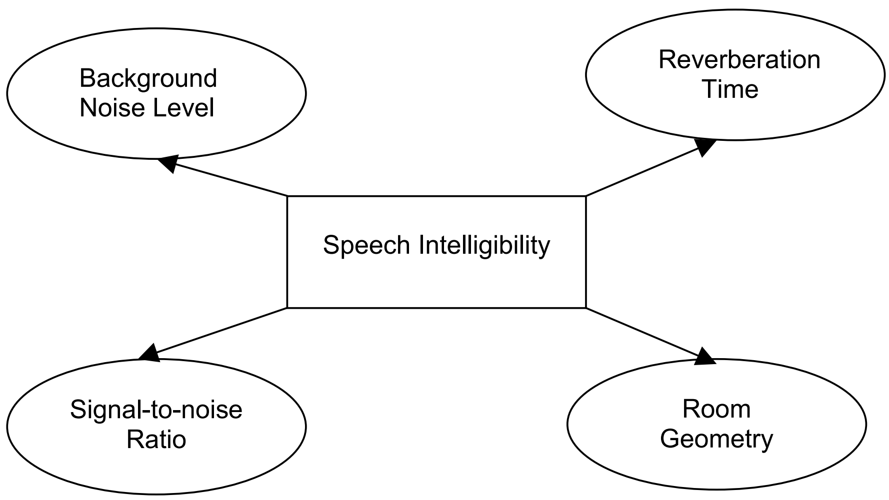
Speech intelligibility is an extremely important acoustic parameter, especially in primary school classrooms, where the spoken word is to be clearly understood. British Standard BS 7827:1996 (4) defines speech intelligibility as “a measure of the proportion of the content of a speech message that can be correctly understood”. A note to this definition states that “satisfactory intelligibility requires adequate audibility and adequate clarity”. For the sake of completeness, the standard also contains the following definitions (4):

- Audibility: “that property of a sound which allows it to be heard among other sounds”; and
- Clarity: “the property of a sound which allows its information-bearing components to be distinguished by the listener”.

Good speech intelligibility, which is a fundamental acoustic property of any classroom or other teaching space, is therefore a combination of audibility and clarity. Four main factors influence speech intelligibility within a classroom setting:

- Background noise level;
- Reverberation time;
- Signal-to-noise ratio; and
- Room geometry.

Fig. 5.1. Factors influencing speech intelligibility



These factors are adequately defined in *Health effects of noise on children and perceptions of the risk of noise* (2) but are briefly defined here.

The background noise level is the noise level generated in a space from all sources other than those arising from the teaching activity being considered (3).

The reverberation time is the time taken for sound to decay by 60 dB and is often given for frequencies centred on 500 Hz or 1000 Hz or sometimes the mean value for both frequencies.

The signal-to-noise ratio is the difference between the signal noise level (such as speech) and the background noise level (such as a fan heater). A ratio of +15 dB is considered acceptable for classrooms.

The room geometry is the architectural style of the room, such as cellular classrooms, open plan or double sloping ceiling.

Thus, the background noise level is influential in determining the speech intelligibility within a classroom or teaching space. So reducing the background noise can create an environment with considerably improved speech intelligibility.

5.2.3. Sources of noise in classrooms

The research project conducted by Heriot-Watt University investigated more than 100 teaching spaces, both occupied and unoccupied. Since all the measurements were carried out in primary schools, the occupants comprised school pupils and their teachers and sometimes classroom assistants. The pupils' ages ranged from 5 to 11 years old inclusive, and most classrooms were fully occupied, with up to 30 children present.

The children were involved in a comprehensive range of acoustic tests. These included such objective tests as background noise level, reverberation time, signal-to-noise ratio, speech transmission index and percentage articulation loss of consonants (%ALcons) and such subjective tests as the word intelligibility by picture identification (WIPI) test.

During the acoustic measurements, children were asked to identify the main sources of noise pertinent to their classroom environment. They did this with great enthusiasm, and the list of noise sources they produced was quite surprising.

The sources of noise present within a typical classroom have three main origins:

- Classroom noise – noise generated from within the classroom itself;
- Internal noise – noise generated from within the school building but outside the classroom itself; and
- Environmental noise – noise entering the room from outside the school building.

Table 5.1. Typical sources of noise found in primary school classrooms

Internal (classroom)	**Internal (school)**	**Environmental (school)**
People noise – talking, chatting, shouting, running etc. Heating systems (such as warm air systems) Ventilation fans Computers Printers Impact of objects on floor School furniture – effect of items dropped on desk tops School furniture – scraping of chairs on hard floor finishes Rain noise on glazed roof lights Rain noise on metal roofs Roof cracking (thermal expansion) Mechanical opening devices for windows Overhead projectors Birds (on roof lights) Fluorescent light fittings	People noise – talking, chatting, shouting, running etc. Impact noise (doors closing) Impact noise from footsteps on hard floor finishes Singing Gymnastics Music Period bells Trolleys	People noise – talking, chatting, shouting , running etc.– especially while playing or during sport or exercise Transport noise: vehicles, aircraft, trains, helicopters Grass-cutting equipment Trees Wind noise Empty heavy goods vehicles on speed-reducing devices Rain impact noise on building components

Source: adapted from MacKenzie & Airey (1)

Some of these noise sources are unavoidable, but most can either be designed out or prevented through good design and careful planning of various elements within the school building.

5.3. Noise in classrooms – the current situation

Most schools in the United Kingdom are going through a process of being inspected. In England this is being carried out by a non-ministerial government department called the Office for Standards in Education (OFSTED). In Scotland, this task is being undertaken by a similar body called H.M. Inspectorate of Education (HMIE).

5.3.1. Office for Standards in Education

The purpose of OFSTED is “to improve standards of achievement and quality of education through regular independent inspection, public reporting and informed independent advice” (5).

The role for which OFSTED is most widely known is the school inspection system that has been established to ensure that each state school in England is inspected every 6 years.

Once a school has been inspected, a report is produced and made available on the OFSTED Web site (www.ofsted.gov.uk). A trawl through some of these reports makes very interesting reading (Table 5.2) (6). The table includes schools selected randomly from numerous reports discussing noise problems. Table 4.1. in the previous chapter gives examples of typical acoustic problems in nursery education premises in England (7).

Table 5.2. Typical acoustic problems in primary schools in England extracted from OFSTED reports

School name	Dates of inspection	Comments on acoustics
Ocker Hill Infant School, Tipton, West Midlands	14–17 May 2001	"Noise transmission is high and this affects pupils' concentration and the presentation of work." (paragraph 66)
Grangehurst Primary School, Coventry	19–22 May 1997	"The high noise level has a significant effect on the quality of pupils' learning. In some lessons pupils find difficulty in maintaining their concentration and this contributes to lower attainment." (paragraph 71)
Deansfield Junior School, Ealtham, London	23–27 November 1998	"A significant weakness of the accommodation is the level of exterior and interior noise, particularly in a few of the classrooms for the lower years of the key stage. Traffic noise, and music or physical education activities, which unavoidably take place in the hall, provide regular distractions from learning. This affects pupils' progress, particularly in oral lessons where pupils occasionally find it difficult to hear their teachers. The general background noise is not conducive to good concentration." (paragraph 72)
Bar Hill Community School, Bar Hill, Cambridgeshire	28 February–3 March 2000	"The open plan design of some of the teaching areas allows an excessive amount of background noise to travel between classrooms. This often makes it difficult for the teachers to teach and the pupils to learn." (paragraph 58)
Stockham Primary School, Wantage, Oxfordshire	7–10 December 1998	"There is significant interference in about a quarter of the lessons from legitimate noise travelling around the building." (paragraph 52)
Mosspits Infant School, Wavertree, Liverpool	26–29 June 2000	"The noise levels during independent work are far too high and children cannot hear each other without shouting very loudly." (paragraph 22)
Eastbrook Primary School, Hemel Hempstead	6–10 March 2000	"Pupils are distracted by noise that is carried easily from one class to another. The design of the classrooms, which are adjacent to each other sharing an open area, means that noise makes it more difficult to hear and concentrate. In conversations with inspectors pupils complained about the noise and the effect it had on their lessons." (paragraph 23)
Nechells Junior & Infant School, Nechells, Birmingham	2–5 October 2000	"However, the noise level in classrooms when pupils are working in groups, or even carrying out independent tasks, is too high to allow pupils to concentrate efficiently; and while they are all getting on with their work, this high noise level slows the pace of their learning." (paragraph 26)

Source: Office for Standards in Education (6)

H.M. Inspectorate of Education

The mission of the HMIE is "to promote improvements in standards, quality and attainment in Scottish education through first-hand, independent evaluation" (8).

The role of the HMIE is the same as that of OFSTED. Once a school has been inspected, a report is produced and made available on the HMIE Web site (www.scotland.gov.uk/hmie).

5.4. Acoustic guidelines for primary schools

Educational buildings are experiencing a building boom throughout the United Kingdom. Many projects are being financed through public-private partnerships. More than £1.2 billion is being spent on two such projects in Glasgow to refurbish existing schools and build new premises. Similarly, work is about to commence on a £360 million school project in Edinburgh financed under public-private partnerships. This project has been called the Investing in Education scheme and will involve building ten new schools and extending and refurbishing five existing schools and three special schools. It will be interesting to see how much acoustics influences the overall design of the school or the classrooms.

As previously mentioned, the main document dealing with acoustics in schools in the United Kingdom is *Guidelines for environmental design in schools*, published in 1997 by the Department for Education and Employment (3). A document complementing these guidelines, *The acoustic design of schools* (9), has not yet been published although it has been promised for some time. This document will deal with acoustic matters and best practice advice on how to achieve the guidelines as described in *Guidelines for environmental design in schools*.

5.4.1. Guidelines for environmental design in schools

Guidelines for environmental design in schools is split into six sections on acoustics, lighting, heating and thermal performance, ventilation, hot and cold water supplies and energy (carbon dioxide) rating. The section of particular interest to this report is Section A on acoustics, that quotes an extract from the Education (School Premises) Regulations 1999 (10):

> Acoustics
>
> 18. Each room or other space in a school building shall have the acoustic conditions and the insulation against disturbance by noise appropriate to its normal use.

A classroom is normally used for a teacher imparting knowledge to school pupils either through the spoken word or written material in the form of a textbook or using a board for instructional purposes. High background noise levels often make this very difficult.

General comments on the guidelines
Guidelines for environmental design in schools advises on how to achieve good acoustic conditions by carefully planning rooms and correctly selecting building elements such as walls, floors and partitions. The guidelines give recommended values for sound insulation, background noise level and reverberation time but no guidelines for speech intelligibility. Since background noise levels have been found to be the greatest noise problem in schools, this is discussed here in detail.

Background noise levels
Table 5.3 shows the background noise levels recommended by *Guidelines for environmental design in schools* for a range of rooms and teaching spaces commonly found in schools.

Table 5.3. Recommended acoustic standards: background noise level

Room type/activity	Activity noise level	Background Noise Level	
	General category	Tolerance level General category	Maximum background noise level from adjacent areas, ventilation and traffic noise $L_{Aeq,1hr}$ (dB)
Music rooms:			
Teaching, listening audio	High	Low	30
Music practice/group rooms	High	Low	30
Ensemble playing	High	Low	30
Recording/control room	High	Low	25
General teaching, seminar and tutorial rooms and classbases	Average	Medium	40
Science laboratories	Average	Medium	40
Language laboratories	Average	Low	35
Commerce and typing	Average	Medium	40
Lecture rooms	Average	Low	35
Drama, play reading and acting	High	Low	30
Assembly/multi-purpose halls[1]	High	Low	35
Audio-visual rooms	Average	Low	35
Libraries	Low - Average	Low	40
Metalwork/woodwork	High	Medium	45
Resource/light craft and practical	High	Medium	45
Individual study	Low	Low	35
Administration offices	Average	Medium	40
Staff rooms	Average	Medium	40
Medical rooms	Average	Medium	40
Withdrawal, remedial work	Low	Low	35
Teacher preparation	Low	Low	35
Interviewing/counselling	Low	Low	35
Indoor sports	High	High	50
Corridors and stairwells	High	High	50
Coats and changing areas	High	High	50
Toilets	Average	High	50
Indoor swimming pools	High	High	50
Dining rooms	High	High	50
Kitchens	High	High	50
Plant rooms	High	High	65

Source: Department for Education and Employment (Architects and Buildings Branch) (3),
Section A: Acoustics

The values in table 5.3 are in $L_{Aeq, 1h}$ and in decibels. $L_{Aeq, T}$ is defined as the equivalent continuous A-weighted sound pressure level over a set period of time T, such as 1 hour; this is a notional steady sound which, over a defined period of time T, would have the same A-weighted acoustic energy as a fluctuating noise. The recommended background noise level for classrooms and other teaching areas is denoted $L_{Aeq, 1h}$; in this case the period T is 1 hour. People who do not have working knowledge of how schools, and in particular classrooms, operate may have difficulty in relating the criterion of 40 dB(A) $L_{Aeq, 1h}$ to the everyday sounds found within classrooms.

Recommended background noise levels in Europe
Many architects in the United Kingdom complain that the recommended limit value for background noise in classrooms of 40 dB(A) $L_{Aeq, 1h}$ is too low. Table 5.4 compares the background noise levels in classrooms within European countries. In fact, 40 dB(A) equates well with most other countries.

Table 5.4. Comparison of standards for background noise levels (dB(A)) for various locations in primary schools for selected European countries

	Belgium	France	Germany	Italy	Portugal	United Kingdom	Sweden	Turkey
Noise descriptor	L_{Aeq}	L_{Aeq}				$L_{eq, 1h}$	L_{eq}	L_{eq}
Year of the standard	1977/1987	1995	1989	1975		1997	1995	1986
Classrooms	30–45	38	30	36	35	40	30	45
Library		33				40	35	
Music rooms	30–40					30		
Hall, corridors				40		50		
Dining, gymnasium	35–50	43		40	40–45		40	60
Craft rooms								
Rooms for people with impaired hearing						30		

Source: International Symposium on Noise Control and Acoustics for Educational Buildings (11)

Annex 7 briefly describes legislation on and regulation of noise in primary schools in Sweden, and Annex 8 does this for the Netherlands. Section 5.6.7 provides an example in which the reverberation time was improved at a school in the Netherlands.

Reverberation time
Reverberation time values must be compared with values for similar frequencies. In some instances, the reverberation time is for 1000 Hz only, whereas others are given for a range of frequencies. Table 5.5 shows the reverberation times for unoccupied spaces recommended by *Guidelines for environmental design in schools* for a range of rooms and teaching spaces commonly found in schools.

The reverberation times given are calculated as the mean of the 500 Hz and 1000 Hz values. In addition, values are given for empty rooms.

Table 5.5. Recommended reverberation times for unoccupied spaces in schools

Type of room	Approximate size		Recommended unoccupied mid-frequency Reverberation Time (seconds)
	Area (m^2)	Height (m)	
Primary schools:			
Classroom or class-base	30 - 65	2.4 - 3.0	0.5 - 0.8
Library	12 - 70	2.4 - 3.0	0.5 - 0.8
Music & drama studio/AV room	30 - 80	2.4 - 4.0	0.8 - 1.2
Hall (assembly/PE/movement)	80 - 200	3.7 - 6.0	0.8 - 1.2
Dining Rooms	80 - 200	2.4 - 3.2	0.5 - 0.8
Hall (music, drama, PE, AVA, assembly)	80 - 200	3.7 - 6.0	0.8 - 1.4
Swimming pool	65 - 120	3.7 - 6.0	< 2.0
Kitchens	65 - 120	2.7 - 4.0	1.5
Secondary schools:			
General teaching classroom	50 - 70	2.4 - 3.0	0.5 - 0.8
Small practical spaces: science, IT, business studies,	70 - 110	2.4 - 3.0	0.5 - 0.8
Large practical spaces: art, metalwork, woodwork, multi-materials, textiles, electronics, food technology	80 - 135	2.7 - 3.0	0.5 - 0.8
Library	90 - 300	2.4 - 3.0	0.5 - 1.0
Hall (assembly/rehearsal)	250 - 550	3.7 - 7.6	1.0 -1.4
Dining rooms	250 - 550	3.7 - 7.6	0.5 - 0.8
Gymnasium/PE	250 - 550	5.0 - 6.0	1.0 - 1.5
Dance studio	150	2.7 - 4.0	0.8 - 1.2
Drama studio	80 - 120	3.7 - 7.0	0.9 - 1.1
Swimming pool	100 - 500	3.0 - 6.0	<2.0
Music rooms:			
Music classroom/recital room	54 - 91	2.7 - 3.5	1.0 - 1.2
Ensemble rooms	16 - 50	2.7 - 4.0	0.8 - 1.2
Small teaching/practice/group room	6 - 10	2.7 - 3.0	0.4 - 0.8
Recording/control room	8 - 15	2.4 - 3.0	0.3 - 0.8

Acoustic recommendations for pupils with hearing and visual impairments

For general teaching rooms, such as classrooms, the recommended $L_{Aeq,\ 1h}$ is 40 dB(A). However, a subsection of Section A on the design of acoustics for pupils with impaired hearing or vision discusses the importance of good lighting and acoustics in rooms with such users (3):

> It is incorrect to assume that school acoustics do not matter if the pupils are severely hearing impaired; even profoundly hearing impaired pupils can detect changes in the intonation and syllabic content of speech. Hearing impaired pupils may use residual hearing as one of a number of means of communication available to them, and good acoustic conditions are required to give pupils the best opportunity to optimise their use of residual hearing.

The section focuses on specialist accommodation for pupils with impaired hearing and lists the various recommended criteria for special schools and special units in mainstream schools designed for teaching children with impaired hearing. In many situations in primary schools, children with special educational needs are being included in mainstream classrooms. Thus, it may be argued that everyday classrooms should meet the recommended criteria for children with impaired hearing or vision.

In all rooms for teaching children with impaired hearing, the maximum background noise level should be 10 dB lower than that in Table 5.3; extra care should be taken to lower the levels of background noise under 500 Hz.

The mid-frequency reverberation time of an unoccupied room for teaching children with impaired hearing should be between 0.3 and 0.6 seconds. (The mid-frequency reverberation time is the mean of the 500 Hz and 1000 Hz octave band values.)

5.5. Guidelines for achieving good classroom acoustics

Achieving good speech intelligibility in open-plan day-care centres and classrooms is a special challenge. The project Children and Noise – Prevention of Adverse Effects therefore asked Claus Møller Petersen, an acoustic engineer, to prepare an overview of the problems and opportunities involved in acoustics in open-plan schools and day-care centres, see Annex 6.

As such, no one publication in the United Kingdom gives adequate guidelines on how to achieve good classroom acoustics in schools, whether primary, secondary or other levels.

Perhaps the easiest way to approach this is to highlight the information given in various articles and publications that cover school buildings. The following are in no particular order.

5.5.1. Metric handbook: planning and design data

A Metric handbook: planning and design data (12) gives in Section 28 detailed information about school buildings in general. It discusses different types of schools (such as nursery, primary, middle and secondary) and presents detailed design considerations for schools.

Section 3.05 on construction and environment states that "Room acoustics remain a crucial element in the success of any school building". In fact, this section has no information on how to achieve these aims.

5.5.2. "Improving acoustics in the American classroom: new guidelines promise better hearing environment for students of all abilities"

Anderson et al. (13) have wide experience in classroom acoustics, and especially in classrooms for educating children with disabilities, and deal with classroom acoustics in general. The situation in classrooms is no better in the United States than in the United Kingdom: "Unfortunately, all too often poor classroom acoustics interfere with listening, learning and ultimately academic achievement" (13).

Anderson et al. (13) discuss the current situation concerning the new acoustic standards proposed for classrooms in the United States currently being developed by the Architectural and Transportation Barriers Compliance Board. Anderson et al. hint at what the acoustic recommendations are going to be based on work published in the American Speech-Language-Hearing Association position statement on acoustics in educational settings (13):

- Unoccupied classroom noise levels should not exceed 30 dB;
- Signal-to-noise ratios at the pupil's ear should exceed a minimum of +15 dB; and
- Reverberation times should not exceed 0.4 seconds.

The original 1995 paper (14) states that the unoccupied classroom noise levels should not exceed 30 dB(A) or a noise criteria 20 dB curve. This paper also states the following.

- Classroom-generated noise, such as pupils talking, desks and chairs scraping on the floor and shuffling books and papers, is the most detrimental, as this form of noise has a similar spectral shape to that of a teacher's voice.
- Classrooms used for teaching children with special educational needs should be located away from external noise sources such as traffic, play areas and equipment.
- Similar classrooms should also be located away from busy hallways and other large group areas, such as gymnasiums and canteens.
- The application of acoustic treatment can help to reduce the noise level and also improve the reverberation time. This treatment could be in the form of:
  – Heavy carpeting;
  – Thick curtains;
  – Acoustic wall panels, especially when applied to hard, parallel surfaces; and
  – Acoustic ceiling panels.

5.5.3. Speech reinforcement systems

Speech reinforcement systems amplify the teacher's voice through a portable microphone and feed it into the classroom via strategically located loudspeakers. They seem to be popular in the United States but not so common in the United Kingdom. Such systems may be used at morning assemblies for the whole school in the United Kingdom but are not so common for classroom situations.

For primary schools, the two-way flow of information from teacher to pupil and vice versa is very important. Primary school teachers often ask pupils for a response or answer to a question. If the teacher has a microphone and is clearly heard, is the pupil's reply lost because of poor acoustics?

5.6. Examples of good practice

Numerous articles have been produced on a worldwide basis dealing with noise in classrooms. They mainly cover the sources of noise and the effects of noise on pupils and teachers. Very little information is available on how to reduce the noise to acceptable levels.

This section discusses several examples of good practice, mainly primary schools, in which the acoustics of various classrooms have been extensively investigated. Four examples (5.6.1., 5.6.2., 5.6.3. and 5.6.7.) are reviewed according to the common framework.

5.6.1. Priory Primary School, Charter Alley, Basingstoke, England

The preventive measure
The installation of sound absorbing material to improve the speech intelligibility in a school hall and also a recently constructed classroom. The material was in the form of an acoustic ceiling.

Characteristics and size of problem to be prevented.
Users of the recently constructed school hall and classrooms explained that the acoustics were poor but could not explain why. The teacher within the classroom was quite adamant that *"there was something strange about the classroom but did not know what".*

A speech intelligibility test was carried out and the percentage articulation loss of consonants (%ALcons) measured at the right hand ear of every pupil within the occupied classroom. This test can show the quality of sound arriving at a person's ear; thus it can be used to determine the sound distribution in a classroom environment.

The results of the %ALcon readings were astonishing, and these are shown in Table 5.6 shown below. Bearing in mind that a maximum %ALcons of 5% is acceptable for classrooms, the majority of the values were well above 5%. In many instances 100% %ALcons were measured. What does this mean? The pupils located at these seat locations are likely to hear sound in the form of the spoken word by the teacher, but it is doubtful whether the pupil would be able to understand what is being said, i.e. extremely poor speech intelligibility.

Table 5.6 Percentage Articulation Loss of Consonants (%ALcons) For Classroom, Priory Primary School, Charter Alley, Basingstoke.

Table 1: %ALcon Values For a Classroom (Before and After Ecophon Acoustic Treatment)

Location (within classroom)	%ALcons (before treatment)	%ALcons (after treatment)	Comment (acceptable value - 5%)
1	9.5	4.0	Improvement
2	9.4	3.0	Improvement
3	6.6	7.3	Slight Increase
4	4.7	2.3	Improvement
5	74.4	3.4	**Improvement**
6	11.2	3.4	Improvement
7	10.2	5.0	Improvement
8	14.6	4.0	Improvement
9	13.7	10.5	Improvement
10	99.0	4.4	**Improvement**
11	7.9	4.1	Improvement
12	12.6	2.8	Improvement
13	100.0	3.7	**Improvement**
14	6.7	3.9	Improvement
15	100.0	3.7	**Improvement**
16	7.1	6.4	Improvement
17	79.5	5.6	**Improvement**
18	87.0	5.3	**Improvement**
19	100.0	8.1	**Improvement**
20	92.0	13.2	**Improvement**
21	11.5	3.4	Improvement
22	12.7	5.3	Improvement
23	8.9	2.7	Improvement
24	5.9	3.9	Improvement

The majority of the children of this primary school use the school hall for one reason or another. Many found it difficult to communicate and understand the spoken word within this room. The classroom was occupied by 30 children at any one time and many found it a difficult room to work in.

The target population for the preventive measure
The classroom was occupied by children in the age range 5 to 6 years old. Normal hearing children found that when in this room, it was difficult to understand the spoken word. Hence children with a hearing impairment would find this classroom a very difficult room to understand the spoken word.

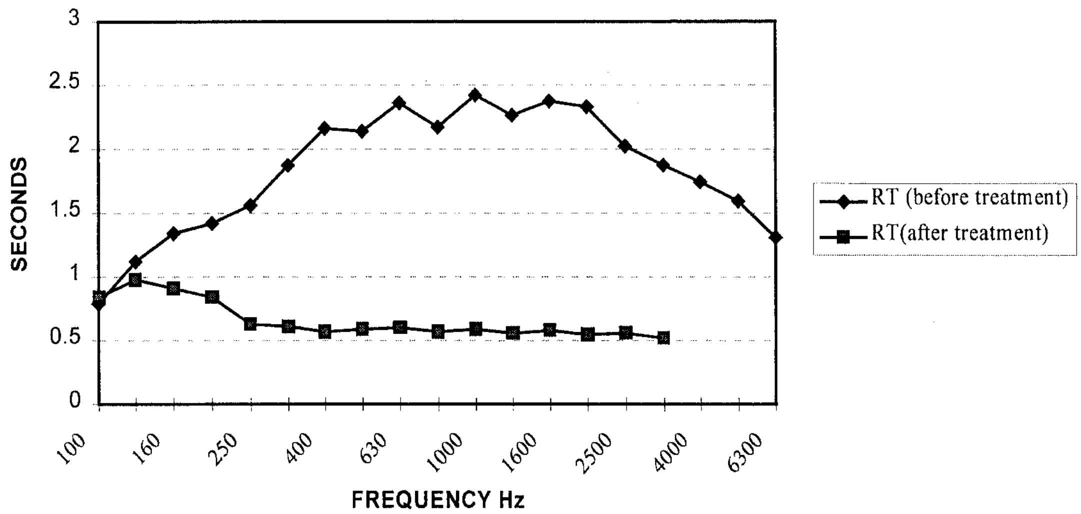
The setting for the preventive measure
Priory Primary School, Charter Alley, Basingstoke, England. This school is located in the countryside away from any major noise sources – or so it would seem. The school is sited near to a major forces training area and consequently there are numerous helicopters flying over the school. With large glazed roof areas, this noise can be very distracting; the only other major noise source is from agricultural machinery. Recently, the school built a number of new classrooms and a general purpose hall constructed in a way to match the existing mid 1800's building. The classrooms are of conventional cellular form.

The hall and classrooms were constructed with exposed ceilings whose lines followed the rafters of the roof construction. Children complained of high noise levels and a strange teaching environment, especially in the new classrooms.

Description of the preventive measure
Hall: the problem was solved relatively easily: acoustic ceiling tiles were fixed directly on the underside of the sloping ceiling, thus removing adverse reflections. Special acoustic wall tiles were fixed to specific sections of the wall surface of the hall.

Documentation of effect of the preventive measure
The improvement to the reverberation time is shown in Figure 5.2.:

Figure 5.2.: Reverberation Times of School Hall, Priory Primary School, Charter Alley, Basingstoke Before and After Installation of Sound Absorbing Panels



Classroom: acoustic ceiling tiles were fixed on the underside of the sloping ceiling, thus removing adverse reflections. The acoustics were remeasured and the percentage articulation loss of consonants showed a dramatic improvement – the new values are also shown in Table 5.6 above. All but one of the %ALcon values meet the required standard for classrooms.

In all, three rooms were treated with sound absorbing material to improve the speech intelligibility within these rooms: one noticeable side effect was the reduction of both the noise level and reverberation time within the treated rooms. Treating the classrooms also had a noticeable effect on the school pupils whose rooms were treated. Many pupils found that they did not have to shout to be heard, as was the case before acoustic treatment; also, there was a quieter environment within the treated rooms.

In all of the research undertaken by Heriot-Watt University, classrooms with unusual ceiling configurations, are likely to create unusual acoustic faults within the teaching space. Classrooms with a rectangular cross-section did not generally exhibit such poor speech intelligibility.

Positive side effects of the preventive measure
The Head Teacher of the Priory Primary School has attended a number of conferences and described the benefits of installing the acoustic ceiling tiles into the school hall and classroom.

These include:

- He has found that since the acoustics have been improved, teachers who use the hall and classroom have been taking less time off due to illness such as sore throats etc. With the money that has been saved in not employing supply teachers, the Head Teacher has now been able to undertake further improvement work to other classrooms of the school, and

- There has been a saving in the energy bill for the treated classrooms: the ceiling tiles have not only been excellent at improving the acoustics of the classroom but also are good at reducing the energy consumption of the rooms in which they are installed.

Adverse effects of the preventive measure
None observed or noticed.

Organisation
All of the acoustic measurement, before and after the installation of the acoustic treatment, were undertaken by personnel from The Department of Building Engineering and Surveying of Heriot-Watt University, Edinburgh, Scotland.

It is worthwhile talking to the teachers who use certain classrooms; they are there for most of the time and are likely to know its behaviour and any faults that may have developed over time;

In many cases, sophisticated measuring equipment is required to actually detect the acoustical problem.

Ethical perspectives
It is common practice in the UK that children with special educational needs are included into mainstream education where possible. Therefore mainstream classrooms should be designed and constructed in such a way that children, whatever their special needs, should be able to use the classroom.

Where-ever possible, the criterion that has been used is that recommended in Building Bulletin 87 ‘Guidelines For Environmental Design in Schools, published by the Department for Education and Employment. There is a section which deals with the design of acoustics for pupils with hearing and visual impairments (3).

Barriers for the preventive measure
Probably one of the biggest barriers is understanding the problems that poor acoustics can create in a building whether it is a kindergarten or primary school. Once the problem is understood, it can be relatively easy to solve the problem and create a much better working environment for pupils and staff alike.

About the existing documentation
Measurements were carried out in the school hall and classroom where staff indicated there was a problem. By carrying out a survey of the room followed by the measurement of the background noise level, reverberation time and speech transmission index (which gives an indication of speech intelligibility), analysis of the results will assist in choosing the correct preventive measure to solve the existing problems.

Links:
It is possible to access the *Office for Standards in Education* (OFSTED), officially the Office of Her Majesty's Chief Inspector of Schools in England at the following web page:

THE OFFICE FOR STANDARDS IN EDUCATION (OFSTED), http://www.ofsted.gov.uk/.
Alexandra House, 33 Kingsway, London, WC2B 6SE

Priory Primary School has recently been inspected by OFSTED and the report for this school can be viewed at the following address:
http://www.ofsted.gov.uk/reports/116/116481.pdf

5.6.2. Balgreen Primary School, Edinburgh, Scotland

The preventive measure
The installation of sound absorbing material to improve the speech intelligibility of a number of classrooms at the school as well as in the school conference room and a room used by children with special educational needs.

Characteristics and size of problem to be prevented
Balgreen Primary School, Edinburgh is a very popular local school and has a high percentage of children with special educational needs. The Head Teacher was particularly concerned about the adverse effect of excessive noise on these children. The school uses natural ventilation, especially in the summer time, to introduce fresh air into the building. However, by opening the windows, noise from the traffic floods into the classrooms, thus causing stress to both staff and pupils alike.

The target population for the preventive measure
A number of classrooms throughout the school were selected for the installation of a suspended ceiling system. The pupil's age ranged from Primary 1 up to and including Primary 7. Other important areas such as a small conference room and a room used by children with special educational needs (across the primary school age range) were also used for this study.

The setting for the preventive measure
Balgreen Primary School is a typical city centre school, located in the heart of Edinburgh. It was built approximately 100 years ago, when no doubt, the volume of traffic and the general sources of noise were much less than what it is now. The school classrooms are of cellular form.

The main sources of noise around this school are as follows:

- Traffic noise, cars, lorries, buses etc. on the busy nearby roads. There is a constant flow of traffic on these roads at all times of the day, especially during class hours;

- There is a set of traffic lights opposite the school which creates additional noise when vehicles, especially public buses, accelerate and de-accelerate at the lights;

- There is a constant noise from trains, both goods and passengers, passing by on the very busy Edinburgh/Glasgow rail line. The fact that the train line is on an elevated position makes the problem of noise from this source more prominent, and

- Near to the school there is a large grassed outdoor bowling green where the grass is cut every morning during the spring and summer period. During the measurements in all of the schools, the school pupils were asked to complete forms which asked them about local noise sources: here the children were adamant that this source of noise was particularly annoying and distracting to them during lessons. This is especially important when windows have to be opened for natural ventilation purposes.

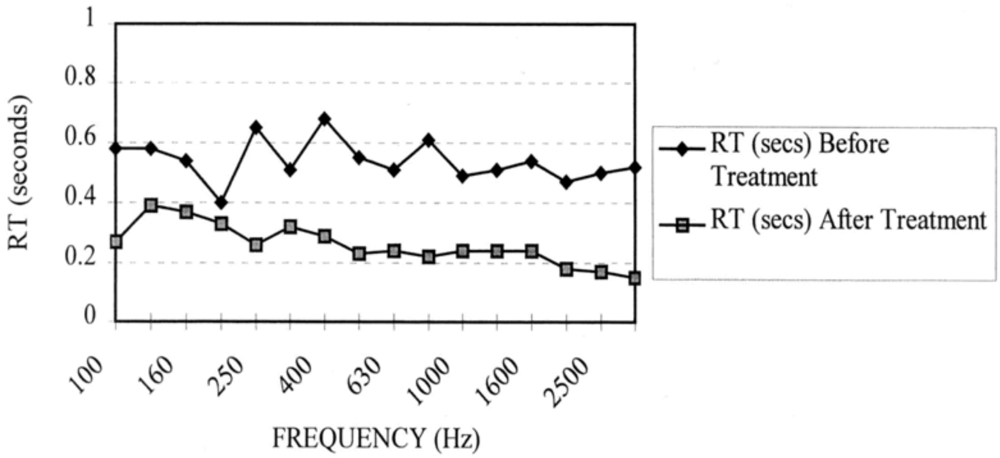
Description of the preventive measure
All of the acoustic remedial work was in the form of the installation of a suspended ceiling system. The ceilings were quickly installed to ensure no disturbance to the education of the school pupils. In many of the classrooms, the large windows posed problems close to the ceiling; this was overcome by angling the suspended ceiling along the edge next to the wall where the windows were located. Great care must be taken to ensure that the preventive method system selected does not change or architecturally change the room being refurbished.

Documentation of effect of the preventive measure
A series of measurements were undertaken in a number of different rooms within this school before and after the installation of acoustic ceiling tiles. Rooms included: primary classrooms, the conference room and a room used for children with special educational needs, which faces onto the busy road junction rendering it virtually unusable.

In all of the rooms treated, the improvement in the room acoustics was very noticeable. The reverberation time was lowered to within the recommended guidelines and the background noise level fell by approximately 6/8dB(A).

Figure 5.3 shows the reduction in the reverberation time of one of the classrooms where a suspended acoustic ceiling has been treated. It may appear that the reverberation time is quite low, however this school has a high percentage of children with special educational needs, many of whom attend school in these classrooms. The Building Bulletin 87 ‘Guidelines For Environmental Design in Schools, published by the Department for Education and Employment (3) give a recommended reverberation time for a classroom used by children with a hearing or visual impairment as between 0.3 and 0.6 seconds (for an unoccupied room at mid-frequency).

Figure 5.3: Reverberation Time in Classroom, Used by children with Special Educational Needs, before and after acoustic Treatment



One of the teachers whose classroom was selected for the preventive measures stated – "The new ceiling definitely makes a quieter working environment. This leads to the children working more quietly and noise is less likely to build up. I don't need to raise my voice as much and the day is much calmer for the children and myself now".

Positive side effects of the preventive measure
This school has been at the forefront of the research that has been carried out in classrooms. The positive attitude of the Head Teacher has allowed numerous visitors to the school to witness the incredible change in the acoustics of the classroom since the installation of the suspended ceiling.

Once the ceilings were installed the children were so proud of their school that they held an open day whereby local people could visit the premises and the pupils gave them a guided tour of the school. A school is not just a building to be used from 8.00am through to 5.00pm – it is an important part of any community and should be seen as such.

Whilst the new suspended ceilings were being installed in this school, various different light fittings were also installed to see whether these had an effect on the overall classroom environment. Most of the light fittings were up-lighters, which is a dramatic change from the conventional down-lighters normally used in classrooms. Some of the lights used were able to be switched from up-lighters to down-lighters.

Adverse effects of the preventive measure
None observed or noticed.

Organisation
All of the acoustic measurement, before and after the installation of the acoustic treatment, were undertaken by personnel from The Department of Building Engineering and Surveying of Heriot-Watt University, Edinburgh, Scotland.

Ethical perspectives
It is common practice in the UK that children with special educational needs are included into mainstream education where possible. Therefore mainstream classrooms should be designed and constructed in such a way that children, whatever their special needs should be able to use the classroom.

This particular school has a high percentage of primary school children who require special educational needs. This has meant the internal environment of the school has had to cater for these needs, whether it is an aural impairment, visual impairment or other.

About the existing documentation
Measurements were carried out in the school hall and classroom where staff indicated there was a problem. By carrying out a survey of the room followed by the measurement of the background noise level, reverberation time and speech transmission index (which gives an indication of speech intelligibility), analysis of the results will assist in choosing the correct preventive measure to solve the existing problems.

Links
HM Inspectorate of Education (HMIE) began operating as an Executive Agency of the Scottish Executive on 1 April 2001. As an Executive Agency, HM Inspectorate operates independently and impartially, whilst remaining directly accountable to the Scottish Ministers for the standards of its work. Her Majesty's Senior Chief Inspector leads HM Inspectorate and has direct access to appropriate Ministers. It is possible to access the HMI web page using the following address:

Her Majesty's Inspectorate of Education
Headquarters Division
G Spur
Saughton House
Broomhouse Drive
Edinburgh
EH11 3XD
Web page: http://www.scotland.gov.uk/hmie/aboutus.htm

Balgreen Primary School has recently been inspected by HMI and the report for this school can be viewed at the following address:
http://www.scotland.gov.uk/hmie/pdf/primary/balgreen_ps.PDF

5.6.3. Scottish Primary School, Strathclyde, Scotland

The preventive measure
The improvement to the acoustics of this school will be undertaken in stages: stage one is the installation of acoustic ceilings fixed directly to the underside of the existing sloping ceilings. Depending on the results of this preventive measure, stage two may be the sub-division of the large open plan areas into smaller class bases.

Characteristics and size of problem to be prevented
This primary school, located in the Strathclyde Region of Scotland, was visited on Wednesday 5th. September 2001 by David J. MacKenzie for the purposes of carrying out an acoustical appraisal of all of the teaching spaces. The school was built six years ago and is of an open plan design.

The school was inspected by Her Majesty's Inspectorate of Education (HMI) in Scotland and the following is an extract from the report, under the section on accommodation: "Throughout the school sound carried easily. The education authority had recognised this difficulty and were taking some steps to investigate how noise levels could be reduced. The school was aware of the need to increase the expertise of some staff in working effectively within open plan areas. The aim should be to improve the learning environment".

Figure 5.4 below shows a view along one of the open plan teaching areas. Within this area there are years 2, 3, 4 and 5. Each academic year has two groups, thus making a total of eight teaching groups. Consequently there are eight teachers with their respective year group, which may be up to 28 children per year (depending on the year), all teaching within the same area.

Figure 5.4 View towards Year 4 and 5 teaching areas, Scottish Primary School

Figure 5.5: Noise Levels Measured at Various Locations Throughout The School

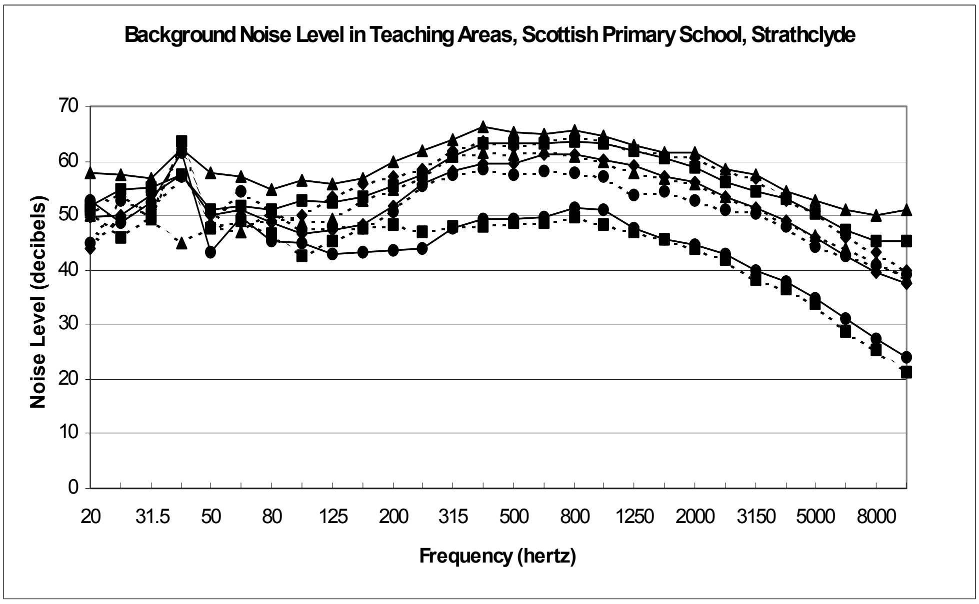
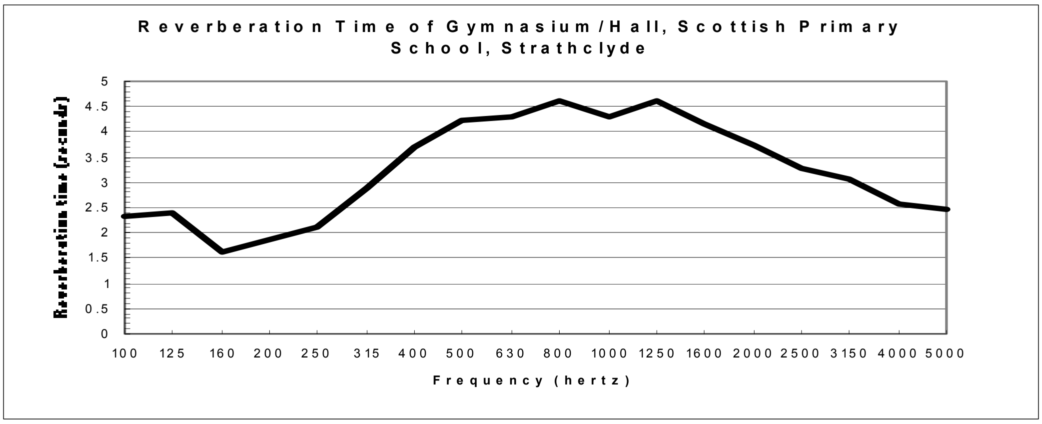


Figure 5.5 shows the upper band of values as the measurement of speech and noise throughout the school, whilst the lower values are noise measurements but without speech. Notice that there is a noise spike at low frequencies, especially at 45 hertz, caused by a noisy ventilation system in a part of the school.

Within the Year 5 area, the background noise level ranges from 63dB(A) for when the group are silent up to 75dB(A) whilst the group are working together, talking, discussing work etc. Teachers constantly have to shout (>80dB(A)) to make themselves heard above the general buzz of noise that exists within this whole area. Whilst the teacher talks to her class (70dB(A)), it is almost impossible for other children nearby not to be distracted by the general high level of background noise that exists.

This school is only six years old, and it must be questioned whether any advice was sought on the acoustics of the school during the design stage. The gymnasium, which is also used as a multi-purpose hall, is another good example of how the acoustics can have a dramatic effect on children. Whilst the children (25 of them) are quiet the noise level is 53dB(A); with the teacher talking to the children the level rises to 71dB(A). The noise level reaches 86dB(A) whilst the children are running back and forth on the varnished timber floor surface and rises to 96dB(A) with the children encouraging each other during competitions or games. The reverberation time within the gymnasium is shown in Figure 5.6. This long reverberation time makes it very difficult to understand the spoken word.

Figure 5.6: Reverberation Time in Gymnasium/Hall



It is vitally important in cases like this to fully understand the scale of the problem within the school complex. A detailed acoustic survey was carried out on the school and the following areas of concern have been identified:

a. High background noise levels throughout all of the teaching areas;

b. High background noise level in the quiet room; the source of the noise is an extractor fan system which is necessary as this room has no windows, being that it is located within one of the class bases. The signature noise from this fan was evident at a number of distant locations around the school complex;

c. High background noise levels within the administration offices resulting from noisy air extraction systems;

d. High reverberation times in specific areas such as the gymnasium/hall;

e. Transmission of sound from rooms such as the music room to teaching areas as a result of pass doors not closing properly, and

f. High external noise levels from the kitchen extractor fans. The location of these fans was very close to one of the teaching areas windows which meant that when the windows were opened for ventilation purposes, it was extremely noisy within the teaching space.

The target population for the preventive measure
An acoustic appraisal was carried out for the whole school, from the class bases used for Year 1 up to the class base for Year 7. The open plan design of the school created a background noise level that was high throughout the school building.

An opportunity arose during the visit to experience the use of a phonic ear, which is used by children with a hearing impairment to magnify the spoken word. A microphone is worn by the teacher and the signal is picked up by a receiver worn by the pupil which is then fed to his/her hearing aids. A major problem exists in the presence of high background noise as the instrument is not able to discriminate between the signal spoken by the teacher and the background noise. It was very difficult to understand what the teacher was saying, and in many cases, pupils using the phonic ear device find it very tiring as they have to concentrate hard to understand what is being said.

The setting for the preventive measure
This recently constructed single storey primary school, is a typical city school where the building occupies a congested site beside a busy road. The school is constructed to a standard design, so there may be other schools which suffer the same acoustic problems.

This particular school does not suffer from external noise sources, such as traffic noise, aircraft noise, etc. but rather from the high noise level generated internally as a result of the open plan design of the school. With up to 240 children and teachers working in an open plan area, split into eight teaching groups, there is little wonder that noise has been identified as a main source of disturbance.

Description of the preventive measure
Following on from discussions with the teaching staff and the school authority, it was decided to tackle this problem in two preventive measure stages:

Stage 1: installation of additional absorption in the form of acoustic ceiling tiles throughout the class base areas, and

Stage 2: erection of demountable partitions sub-dividing the area into separate teaching bases.

Stage 1 is currently underway: since the ceiling has many glazed areas which allows light into the class bases, these are proving to be quite difficult to deal with, and requires a great deal of cutting and fitting tiles around them.

Documentation of effect of the preventive measure
The installation of acoustic ceiling tiles has proven to be very successful in a number of previous projects. These tiles have been used to reduce the reverberation time to acceptable levels, to lower the background noise levels and to improve the speech intelligibility within the classrooms.

Positive side effects of the preventive measure
To be assessed.

Organisation
All of the acoustic measurement, before and after the installation of the acoustic treatment, are undertaken by personnel from The Department of Building Engineering and Surveying of Heriot-Watt University, Edinburgh, Scotland.

Ethical perspectives
It is common practice in the UK that children with special educational needs are included into mainstream education where possible. Therefore mainstream classrooms should be designed and constructed in such a way that children, whatever their special needs should be able to use the classroom.

5.6.4. Donaldson's College for the Deaf, Edinburgh, Scotland

Donaldson's College for the Deaf describes itself as follows (15).

> Donaldson's opened in 1850. From the beginning until 1938 both hearing and deaf children were taught at the College. Education alongside hearing children has remained a central part of our programme. Children attend local mainstream schools for selected subjects and take part in their activities and children from mainstream schools come to Donaldson's to take part in our activities.
>
> Integration and involvement are important words to us. They apply as much to parents as to children. We want parents to be partners with us in the development of their children.
>
> Because of its long historical links with deafness the College is a focal point for activities associated with deaf issues. Deaf associations frequently hold conferences, meetings and social events here. The children participate in some of these, which broadens their experience of the wider world and develops their confidence and self-esteem.

Donaldson's College for the Deaf is located in the heart of Edinburgh and occupies a large imposing building surrounded by formal gardens. In 1998, plans were submitted for the construction of two new education blocks:

- A new nursery and primary block for teaching hearing-impaired children; and
- A new technology block for teaching technology subjects such as computing, art and design.

Although Heriot-Watt University was not involved in the actual design of both buildings, the author was asked to appraise the acoustics of both buildings. This involved appraising both buildings in terms of:

- Sound insulation, both external and internal and also internal between rooms;
- Room acoustics, with respect to reverberation times and noise levels;
- Material selection for all room surfaces;
- Selection of appropriate equipment that could be used within the teaching spaces, such as totally silent overhead projectors;
- Selection of the equipment that could be used within the technology spaces, including such factors as the sound pressure level of band saws and planers in operation; and
- The building services installation, including ventilation systems and any other noise sources that might cause a problem to the pupils, most of whom wear hearing aids.

The project commenced by measuring the background noise levels around the proposed building site, which is located to the rear of the existing building in Edinburgh. Several mature trees are close to the location of the two new buildings, which are located next to each other. Since the two buildings are naturally ventilated, the action of opening a window may cause high noise levels within the classrooms as a result of tree noise (such as the wind rustling the leaves or branch noise). A number of aircraft also fly overhead as they approach Turnhouse Airport in Edinburgh for their final approach from an easterly direction.

Each and every room was carefully designed, considering the use of the room, the reverberation time and noise levels. The predicted reverberation time was calculated by determining the area of every piece of surface material in the room; knowing its absorption coefficient made it possible to determine the maximum absorption area of the room and then to calculate the reverberation time. *Guidelines for environmental design in schools* (3) was used as a guideline as to the acceptable reverberation times within the numerous and varied areas.

A close relationship with the design team was important at all times to ensure that the design detail of each room was fully understood and that any suggestions as to how to achieve the appropriate acoustics requirements of each room were feasible. It is also equally important to understand how products work or how a construction process works in practice: for example, the original design contained a large glass prismoidal roof over a large internal courtyard, thus allowing as much light into the courtyard as possible. However, heavy rain falling on the glass roof could create a high noise level within the courtyard, which may prove to be detrimental to the hearing-impaired children, most of whom wear hearing aids.

A recent visit to the school and a discussion with the school's principal has highlighted the success of both buildings from an acoustic viewpoint. Teachers and pupils alike are happy and obviously proud of their new environment. Nevertheless, one or two small problems need to be resolved, such as acoustic pads under computers to avoid vibrations on the desk, which can be distracting to hearing-impaired pupils. Pupils with impaired hearing tend to use the sensation of vibrations much more than do people with normal hearing. For example, to determine whether a machine or piece of equipment is operating, a person with a hearing impairment would sense any vibrations, thus determining whether it is operating or not.

5.6.5. Acoustic appraisal of a new primary school in Edinburgh

This acoustic appraisal was carried out by David J. MacKenzie and Sharon Airey from the Department of Building Engineering & Surveying, Heriot-Watt University on 13 July 2000. This is an example of a critical analysis of design plans for a new school with acoustics and noise in mind.

During the process of designing a group of new primary schools, the author was asked to inspect the design of one of the proposed primary schools, to be located in Edinburgh. The following indicates the major acoustic aspects that were noted. The titles refer to specific areas within the school and are included here to show the type of area in which acoustic problems can arise.

Toilets next to the staff room
The partition separating the toilets from the staff room must have acceptable sound insulation.

Boiler and information technology room
The separating wall between this room and the hall will have to be designed to prevent the transmission of sound through this wall.

Nursery toilets
Since this is an internal block, some form of ventilation will have to be provided, which should be quiet enough to avoid disruption in the nursery.

Main entrance area
There should be another set of double doors inside the main entrance door to create a sound and security check. The sound check is to prevent any external noise being transmitted into the hallway of the school, and especially when the hall is so close to the main door. These doors would also provide a security check whereby a person entering the school would get through the first set of doors and be attended to by personnel in the main office. Acceptable people could get though the second set of doors and then into the school complex.

Roof details
Details of the roof construction are not provided, but if a lightweight structure is to be used with a thin metal covering such as steel or aluminium, the problem of rain noise or drumming on the metal roof must be considered. This is also pertinent if roof lights are to be used.

Hall
The hall of a school tends to be a multi-functional room used for all sorts of activities. Good acoustics is therefore imperative in a teaching or entertainment environment. The use of adequate and correctly placed sound-absorbing material helps to reduce the overall noise level and reduces the reverberation time. This will create good speech intelligibility within the hall environment. A school hall tends to be a focus point for the school and is often used for community purposes as well as for school purposes.

Access to the hall is shown as being from the entrance area. This hall is likely to be used for a number of noisy uses, such as gym classes, music lessons and play rehearsals. In other words, it is liable to be noisy. However, it is close to the administration area of the school, where there are meeting rooms etc. Providing doors as shown is unlikely to reduce the noise to an acceptable level. Once the door of the hall is opened for access, any noise is likely to go into the corridor and may be a nuisance.

The separating wall between the hall and the kitchen should have adequate insulation against airborne sound. Kitchens tend to be noisy at the best of times, and performances have often been disrupted by kitchen noise. If there is going to be a worktop along the wall between the kitchen and the hall, this will have to be carefully thought out to prevent impact noise on the worktop from passing the wall and into the hall.

Hall changing area
The changing area for school pupils who will use the hall is shown next to the main hall area. (The room in the middle of this area – is this a toilet for disabled people?) Pupils changing in this area have to leave the changing rooms and go into the main entrance corridor and then into the hall. Again, this is directly opposite the administration area of the school, where visitors may be waiting and/or a meeting may be held in the meeting room. Children going into the hall to play games are likely to be quite excited and therefore noisy in an area that should be fairly quiet.

General corridor on the ground floor
No doors are shown compartmentalising this corridor into areas. Will these be included, as they are ideal not only for preventing fire but also for preventing noise from passing along the corridor from, for example, the hall into the class area, which is semi-open plan?

Acoustic aspects of class bases
Some general comments on the general acoustic design of the class bases are as follows.

- The overall projected number of pupils in the school is 462; this works out to about 33 pupils per class base. With two class bases per year, that is, 1, 2, 3 etc., this gives 66 pupils within each year group. It is quite usual to have a teacher in each class base; peripatetic teachers, learning support teachers and parents of certain pupils may also be present in a class base. The noise level created within one class base may therefore be quite different to that of the adjacent class base although the pupils are of the same year level.
- The actual layout of each class base is very important: in which direction will the pupils face, that is, where will the teacher's base or desk be?
- Many open-plan or semi-open-plan classrooms have a quiet area in which pupils can sit and read books or engage in other activities in peace and quiet. Is this going to be provided?

- The general work areas are located outside the actual class base, next to the corridor. These tend to be noisy because of the nature of the lessons taking place: however, they are also the closest to other class bases, and so the noise level has to be carefully controlled.
- Children often have class tests within their own class bases, and keeping the noise level within these areas to a minimum is therefore essential.

Acoustic design of class bases
Some general comments on the acoustic design of the class bases are as follows.

Research has clearly shown that having sound-absorbing material in a classroom, or any room, can:

- Lower the background noise level in the room;
- Reduce the reverberation time of the room;
- Improve speech intelligibility within the room;
- Create a much better teaching environment for both teacher and pupils; and
- Control the noise level of specific items of equipment within the classroom.

The following measures are therefore recommended.

- The ceiling should have sound-absorbing material to counteract the effect of dead spots and reflection of sound from one class base to the other.
- Sound-absorbing material should be placed behind the computers to prevent sound from reflecting from the computers into the teaching spaces.
- A row of screens should be placed alongside the corridors on both the ground floor and lower ground floor to separate the various class bases on either side of the corridors. These screens should absorb sound and have an appropriate height, such as 1.2 or 1.4 metres.
- These screens will allow access into the various class bases but will cut off the line of sight for the pupils within the different class bases.
- Because the screens will absorb sound, they will help to create a better working environment within the class bases.
- Since the screens will not be full height, they will still allow daylight into the various areas.
- These screens can also be used (to a limited extent) to display material; however, the more material that is put on the screens, the less effectively they absorb sound.
- An appropriate floor finish must be used on the upper floor to reduce impact sound being transmitted through the floor structure into the lower floor.

Separating floor between the ground floor and the lower ground floor
The floor that separates the ground floor and the lower ground floor must be designed to insulate sound well. *Guidelines for environmental design in schools* (3) gives recommended sound insulation values for different classroom conditions. However, this is for airborne sound insulation only; this floor must also be insulated against impact sound (such as footsteps), which can be a major source of distraction.

Canopies around the perimeter of the building
Canopies around the perimeter of the building have to be carefully designed: experience has shown that they are constructed of lightweight metal and have a hollow construction. Rain may therefore cause a drumming effect: if the class base windows are open, this noise can be intrusive within the class areas.

Environmental noise
Have the sources of environmental noise around this school building been assessed? The direction of the front door of the school is important: is the door facing private residential buildings, as shown for some of the schools, or what?

Stairs with primary school
Impact noise from stairs is always a source of complaints. Care will have to be taken to ensure that they are properly designed and that there is no possibility of sound being transmitted through the support walls and into the class bases.

Lift
Where is the lift motor room being located? If it is on the roof, sound may be transmitted throughout the steel framework of the building.

Equipment noise
Computers, printers and photocopiers can all be quite noisy and must be carefully located to reduce as much noise as possible.

Television and video presentations
Many schools use television and video presentations: where will these be held so as to prevent noise annoyance in other class bases?

5.6.6. Increased speech intelligibility and order in a classroom after acoustic treatment at Primary School De 4 Heemskinderen, Etten-Leur, the Netherlands

The preventive measure
Placing acoustic ceilings in a classroom.

Characteristics and magnitude of the problem to be prevented
The speech intelligibility is reduced in certain classrooms with poor acoustics. Children's behaviour and proper teaching might be affected by noise in classrooms. There might be a socioeconomic burden caused by the problem due to decreased learning capabilities in schoolchildren.

The target population
Pupils in Primary School De 4 Heemskinderen in Etten-Leur, the Netherlands.

The setting
A case study was carried out comparing reverberation time and student behaviour in two classrooms, one equipped with acoustic tiles and one without.

Description
One classroom was treated with a class A acoustic noise-absorbing ceiling and another classroom was not treated. The aim was to study the influence of this measure. For example, the reverberation time was measured with and without children in the treated and the untreated room.

Assessing the acoustics of a classroom requires knowing:

- The reverberation time;
- The power of direct sounds;
- The power of reverberated sounds;
- The power of diffuse sounds.

Documentation of effect
The average reverberation time (over 500–4000 Hz) in the classroom treated with an acoustic ceiling was 0.41 seconds and in the untreated rooms 0.96 seconds. Both classrooms were unoccupied. The surface of both classrooms was 55 m^2, and the effective absorption coefficient of the acoustic ceiling was good.

In the untreated room, each pupil present contributed additional equivalent absorption area of 0.22 m^2. In the treated room there was little difference in the reverberation time between the empty and occupied classroom (Table 5.7).

Table 5.7. Effects of installing acoustic tiles in a classroom at Primary School De 4 Heemskinderen, Etten-Leur, the Netherlands

frequency >	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	mean 500-4000 Hz
classroom I, with acoustic ceiling, *unoccupied*	0.68	0.45	0.43	0.39	0,41	0,42	0,41
classroom II; without acoustic ceiling, *unoccupied*	1.13	1.12	1.04	1.00	0,96	0,85	0,96
classroom II; without acoustic ceiling, *occupied*	1.10	0.95	1.00	0,84	0,76	0,7	0,83

During lessons, the noise level in the treated classroom was 8 dB(A) lower than that in the untreated classroom. When the noise levels were being measured, activities were observed and the cause of about 30 peak sounds, such as shifting chairs, shouting, teacher silencing the children, etc. were noted in the noise report (16).

The speech intelligibility is measured using percentage articulation loss of consonants.

According to the report (16), the percentage articulation loss of consonants in an empty treated classroom is 3.2%, which is considered good, and 7.6% in an empty untreated room, which is fair.

The children’s behaviour was observed in the two classrooms, and orderly and disorderly situations were noted. Disorder could follow a situation in which the teachers give a lesson and then leaves the room, with children studying independently. The noise levels rose from 44 dB(A) to 68 dB(A) and then declined to 50 dB(A) when the teacher re-entered.

Positive side effects
The teacher in the room with acoustic tiles found restoring order easier than did the teacher in the room without acoustic tiles. A classroom with acoustic ceilings has lower average peak noise levels.

Adverse effects of the preventive measure
None, except that the reverberation time should not get too short as teaching might become difficult.

Organisation
An acoustic consultant advised on the correct sound-absorbing ceiling to reach the right amount of sound absorption.

Cost
The cost of the acoustic ceiling; depending on the size of the classroom, this is a one-time expense.

Benefits
Health improvement in a broad sense.

Ethical perspectives
Very acceptable, no potential ethical implications and risks.

Barriers for the preventive measure
The cost of installing the acoustic ceiling may be seen as a barrier.

Existing documentation
A report on the study (16) and measurements by Consultants Peutz & Associes B.V.

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The review is based on an interview by Marie Louise Bistrup with M.P.M. Luykx of Consultants Peutz & Associes on 21 August 2001 in Molenhoek, the Netherlands. Ruud Geerligs, Ecophon, the Netherlands, kindly provided the report (16) and reviewed this description.

5.6.7. Feedback from staff and pupils after acoustic treatment

The feedback from pupils and staff from schools at which acoustic remedial work has been undertaken has been remarkable. During the research process, several presentations have been given to parents of children during parent–teacher meetings, who found the whole process of improving the acoustics worthwhile.

The following is a list of comments made by pupils who are now being taught in an improved acoustic environment.

- “We can hear much more ... we don’t have to shout across the table, our teacher is in a better mood and doesn’t have to shout.”
- “It has made us want to be quiet.”
- “I’m not as tired and stressed out at the end of the day as I used to be. It also means that my teacher doesn’t lose her voice any more.”
- “The lower noise levels have a calming effect on the pupils.”
- “This calming effect is particularly important for children with special educational needs.”
- “Why cannot all the rooms be treated?”

Several teachers indicated how calm the pupils were in a quiet acoustic environment. This was especially evident for pupils with special educational needs, such as pupils with impaired hearing or vision. The fact that teachers do not have to shout to make themselves heard can only be a good thing for all concerned. During our visit to Kilbowie Primary School, it was rather disconcerting when a teacher had to shout at a pupil for some particular reason.

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6. Preventing adverse effects of noise in discothèques

by Susanne Neyen

6.1. Background

In the last three decades, the number of adolescents with a clear decline in hearing ability has increased (1–6).

Extensive studies have found that leisure activities are inducing this hearing loss. When the hearing impairment began, most of the adolescents did not have any substantial exposure to occupational noise (7).

This hearing impairment caused by non-occupational noise is called *socioacusis*, similar to presbyacusis, which is hearing loss occurring with age (8).

The number of young men in Great Britain exposed to loud noise in leisure activities increased more than three times from 1980 to 1990. Meanwhile, the number of jobs in which workers were exposed to loud noise halved in the same period (9).

Researchers began to indicate the possible risk of hearing loss through amplified music in the 1970s. Since then, the music load of adolescents has increased, especially through the increasing use of portable music players in the 1980s, a shift in the ages at which children begin to use such devices, attending discothèques and live concerts and attending noisy techno events usually lasting all night.

In Norway, the percentage of adolescents with moderate hearing loss increased from 16% in 1981 to 36% in 1987 but declined to 25% in 1992 because of intense information campaigns (2).

Hearing impairment also increased dramatically in Switzerland: about 20 dB at the frequencies of 3 to 6 kHz among boys and girls aged 15–18 years from 1976 to 1991 (4).

The trend in Germany is similar. About 24% of 1800 men aged 16–24 years subject to compulsory military service had a noticeable 4 kHz notch (7). The increasing use of portable music players was discussed as a possible cause.

Excessively loud music levels have been shown to cause irreversible hearing loss (3, 10).

In addition to loud music, acoustic trauma caused by fireworks or toy guns and air guns plays a great role in inducing hearing impairment (11).

A study showed that, in addition to loud music, contact with toy pistols is an essential noise source in children's exposure to leisure noise (12). Of the 358 children surveyed, 77% indicated that they play with toy pistols. Of that number, 68% indicated that the contact was "rare" and 9% "regular". Of the pupils who played with toy pistols, 31% remembered subsequent ringing in their ears.

West & Evans (13) found that 19- to 23-year-olds who reported experiencing noise exposure over a longer period had significantly greater depression at 3.5–6 kHz than did the less burdened group of 15- to 19-year-olds.

The Commission on Socioacusis (focusing on hearing loss from non-occupational noise exposure) of Germany's Federal Environment Agency explained in January 1995 that "according to contemporary scientific knowledge, listening to loud music risks permanently impairing hearing" (14).

Sound levels of 100 dB(A) are common at discothèques and concerts, with peak levels exceeding the pain threshold of 120 dB(A). This corresponds to the sound load of a low-flying military jet.

Impairment is therefore frequent. Nevertheless, the physiological and mental harm caused by noise usually arises gradually, at first imperceptibly for the people affected and first recognised after years. Thus, adolescents are not conscious of the harm.

The increasing number of hearing-impaired adolescents comprises a basis for concern and creates a need for rapid action in passing legislation that guarantees protection and ensures that parents and teachers teach adolescents about the existing risk. Last but not least, the organisers of concerts with loud music and the manufacturers of music devices and sound-making toys should become conscious of the health needs of children.

6.2. State of the research on hearing impairment caused by loud music

6.2.1. Origin of hearing impairment

Noise-induced hearing impairment is defined as loss of hearing exceeding 40 dB at 3 kHz (15).

The qualities of human hearing are oriented towards the sound signals emerging from natural environments. Some noises caused by industrialised environments, however, exceed the loudest natural sources in strength and duration.

Sound energy is decisive in impairing hearing. The risk of impairment increases with the sound level and the duration of exposure.

Inner ear damage develops from the impact of high sound intensity at sound pressure levels above about 80 dB(A).

The damage occurs primarily within the pillar cells in the organ of Corti of the inner ear. This initially results in temporary hearing loss that is reversible and characterised by a temporary increase in the auditory threshold within a certain regeneration stage. In the second stage, the functioning of the pillar cells is permanently damaged, as they cannot recuperate or only in part. In the third stage, the pillar cells are irreversibly damaged. When hearing loss caused by noise begins, hearing ability is restricted in the upper frequency range with a typical depression around 4 kHz. Further noise exposure also impairs hearing ability for low frequencies.

The sound threshold for absolutely avoiding all noise-induced hearing loss is about 70 dB(A). For this sound level, it is assumed that regeneration processes are acting simultaneously with the impact of the noise (16).

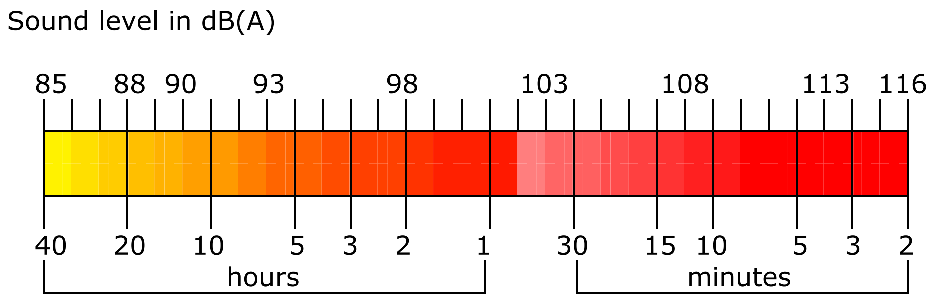
6.2.2. The principle of energy equivalence

Damage to the inner ear caused by noise depends on the frequency, the sound pressure level and the duration of exposure. The stronger the sound pressure, the shorter the duration of exposure that is required to induce impairment. The converse is also true: the longer the duration of exposure, the lower the sound pressure that is required to induce damage.

The principle of energy equivalence states that only the total noise energy determines the scale of the resulting impairment. This is the equivalent continuous sound level over a working time of 8 hours per day ($L_{Aeq,\ 8h}$). According to the principle of energy equivalence, the sound level (L_{Ar}, defined as $L_{Aeq,\ 8h}$) is used in Germany to assess the risk to hearing induced by noise (Fig. 6.1) (17).

Sound level in dB(A)

Fig. 6.1. Permissible weekly duration of occupational noise exposure in Germany



The general rule is that a long duration of exposure to effective sound pressure exceeding 85 dB(A) may induce hearing impairment, although individual sensitivity differs. The range of variation is 5–10 dB(A).

According to the principle of energy equivalence, a 3 dB increase in the sound pressure level doubles the sound intensity (18). A 10 dB increase in the sound pressure level increases the sound pressure by ten times.

However, the principle of energy equivalence does not take into account whether there are noise-free resting times during which hearing can be regenerated.

6.2.3. Estimating the risk of hearing impairment according to ISO 1999

ISO 1999 (19) standardised the estimation of potential hearing damage induced by occupational noise. The standard indicates the sound energy dose impacting the ear, calculated from the time integral of the squared effective sound pressure during work. The impaired hearing caused by the noise is determined directly from the absorbed dose. Since research results have verified that industrial noise and music noise are equivalent at the same dose, the calculations valid for industrial noise can be applied to the harmful effects of music (20, 21).

Assumptions based on ISO 1999 reveal that just a few regular visits to a discothèque can increase the risk of long-term hearing impairment. Babisch & Ising (22) from the Institute for Water, Soil and Air Hygiene of Germany's Federal Environment Agency researching the effects of noise calculated that a weekly discothèque visit of 3 hours with an average noise level of 102 dB(A) means more noise exposure than would be permissible for workers in highly noise-exposed areas. Babisch & Ising (22) showed through parameter curves for the determination of the risk of hearing impairment among groups of adolescents that solely listening to music with headphones will cause about 10% of adolescents to lose hearing of at least 10 dB at 4 kHz after 5 years. After 10 years, 0.3% of the adolescents will already have noticeably limited ability to hear language. Additional discothèque visits increase the risk of hearing loss.

Combining the sound levels measured in discothèques with the frequency of visits according to the principle of energy equivalence results in the following according to ISO 1999: after 10 years, 10–20% of the adolescents would have slight but verifiable hearing loss of >10 dB at 3 kHz (23).

Recovering from excessively loud music at discothèques and concerts or from occupational noise requires sound levels under 70 dB(A). The recovery time needed is often not achieved because of the subsequent use of headphones at levels exceeding 70 dB(A). The combination of discothèque visits and noise through headphones with portable music players or computer games thus presents a risk (12, 23).

6.3. The sound level at discothèques

The noise level at rock concerts and discothèques can cause hearing impairment. This problem has been researched for about 3 decades (3, 5, 24–26).

Noise levels in bars and discotheques vary across the rooms, from bar to dance floor etc. as illustrated by examples of noise measurements in Scotland, table 6.1.

Table 6.1: Noise levels in bars and discothèques, Scotland

Job No.	Noise Source	Notes	L_{Aeq}
16	Music/Speech	Around bar	**86,1**
272	Music and Speech	In bar at table	**81,3**
272	Music and Speech	In bar at table	**79,6**
272	Music and Speech	In bar at table	**80,5**
278	Music and Speech	Upper Bar	**83,1**
335	Music	Main Bar	**89,3**
138	Music	Dance Floor	**88,0**
278	DJ and dance floor	Edge of dance floor	**88,8**
278	DJ and dance floor	Edge of dance floor	**89,3**
278	DJ and dance floor	Edge of dance floor	**91,1**
278	DJ and dance floor	Edge of dance floor	**92,6**
141	Karoake	Bar Entrance	**86,5**
141	Karoake	Stage	**84,5**
200	Karoake	About 4m from speakers	**78,6**
200	Karoake	About 4m from speakers	**95,7**
200	Karoake	About 4m from speakers	**81,9**
9	Disco	On dance floor	**98,2**
9	Disco	On dance floor	**97,2**
9	Disco	On dance floor	**95,4**
9	Disco	On dance floor	**97,7**
184	Night Club	Perimeter of Dance Floor	**99,5**
184	Night Club	Perimeter of Dance Floor	**101,2**
27	Wedding band	Edge of dance floor, ~ 5m	**91,3**
27	Wedding band	Edge of dance floor, ~ 5m	**90,8**
262	Band at Wedding	Edge of dance floor	**87,8**
51	Rave, Main Hall	~18.5m back, off axis	**92,9**
51	Rave, Main Hall	20m back, on axis	**96,1**
51	Rave, Main Hall	2.5m back, on axis	**104,7**
51	Rave, Chill Room	2.5m back, on axis	**107,5**
359	Disco	Edge of dance floor	**90,7**
359	Disco	Edge of dance floor	**90,0**
365	Pub with DJ	1/2 way up stairs to gallery	**94,1**
365	Pub with DJ	Gallery	**94,8**
365	Pub with DJ	Quiet Room off Gallery	**86,2**
365	Pub with DJ	1/2 way up stairs to gallery	**99,1**
365	Pub with DJ	Centre of Main Bar	**95,2**
365	Pub with DJ	1/2 way up stairs to gallery	**93,6**
394	Juke Box	Middle of games room	**69,2**

Source: Charlie Flemming, acoustic consultant, Scotland

In 1984, the Austrian Health Institute (ÖBIG) published the results of an extensive investigation of the noise levels in discothèques (27). The equivalent average sound levels were between 87 and 104 dB(A), and peak levels reached 94 to 113 dB(A). In the years 1988 and 1994, the sound level on the dance floor was clandestinely measured in various discothèques in Berlin (3, 5). The average noise level was between 89 and 110 dB(A), and the distribution maximum was about 100 dB(A). The music volume increased during the night at about 2 dB per hour.

A random sample of sound measurements in discothèques and at live music events in other cities and countries confirm these measurements. The usual music sound levels are between 90 and 110 dB(A), but on the dance floor the average sound level is around or over 110 dB(A) (3, 11, 26–36).

The reasons the disk jockey or event organiser increases the sound level include:

- The discothèque is not as full in the beginning, producing less ambient noise to be drowned out;
- The atmosphere and the mood of the patrons are to be built up slowly; and
- The temporary threshold shift of the disk jockeys and the patrons levelled out during the evening.

Annex 9 describes an example in which noise exposure was determined at discothèques in Reggio Emilia, Italy.

The question is whether the hearing loss is balanced out unconsciously or consciously. Depending on the answer, there are different ways to reduce the sound level. Inadvertent increases in volume could be avoided by educating the disk jockeys or the organiser about the danger of high noise levels. In contrast, administrative means will be unavoidable in case of deliberate increases in the sound level.

6.4. Music-listening habits of children and young adults

The most popular noise-intensive leisure activity is listening to music. Various studies have examined whether age, gender and type of school influence music-listening habits in a statistically significant manner.

Studies showed that the noise exposure from portable music players and discothèque visits varies according to age (5).

Among children 10–11 years old, the sound exposure largely comprises listening to music using portable music players. At 17 years, the sound exposure at discothèques increases noticeably, and the proportion of exposure induced by portable music players decreases.

The entrance age for discothèques in Germany and the Netherlands averages 14 to 16 years (10, 11, 37).

The results of surveys among adolescents asking about their habits in music listening and/or frequenting discothèques show that the frequency of using portable music players increases during puberty and declines later. Ising (5) found that the average daily time spent listening to music climbed from 1.3 hours at age 12 years to 2.7 hours at age 16 years and then declined again slightly until age 18 years. One of 10 adolescents listened to music 5 hours or more daily. The duration of time spent in discothèques increased from 0.9 hours per week at 14 years to 2.5 hours at 16 years and levelled off among older ages.

Other studies in Germany confirm this trend. Struwe (7) found that 64% of 16-year-olds frequented discothèques and dance events, and this increased to 78% among 19-year-olds. The interest declined again beginning at age 21 to 71% and to 28% at 24 years.

The amount of time spent at discothèques was especially high at 18–22 years old: 7 hours weekly, whereas both the 16-year-olds and 24-year-olds averaged 5 hours weekly.

Studies of 681 pupils from Detmold, Germany found similar results for listening to music (38). Seven per cent of those 10 to 13 years old had a daily sound exposure ($L_{Aeq,\ 8h}$) ≥95 dB(A). The 14- to 16-year-olds had the highest noise load, with about 10% being exposed to $L_{Aeq,\ 8h}$ ≥95 dB(A). The load decreased again with increasing age. Only 5% of the 17- to 19-year-olds had a $L_{Aeq,\ 8h}$ ≥95 dB(A).

Schuschke et al. (10) examined the music-listening behaviour of 1117 urban adolescents; the 16- to 18-year-olds listened to the most music.

According to a survey of 10,000 adolescents, about 10% listen to music very extensively. Nevertheless, these people are usually scarcely noticed in the reports of new studies (22).

Ten per cent of the 12- to 18-year-olds surveyed visit a discothèque 4–8 times per month, whereas the average adolescent frequents discothèques or rock concerts only once or twice monthly, depending on age – with older people visiting a little more often.

In conclusion, these studies have statistically demonstrated that music-listening behaviour differs according to age group.

Compared with statistics from 1984, the data listed above show that adolescents today visit discothèques 2–3 years earlier. In addition, the average number of years during which young people visit discothèques may be longer. This has been about 10 years. The stage of using a portable music player frequently lasts 5–10 years (23).

Nevertheless, more and more young children use these devices. Preschoolers often use such a device, and the toy industry attracts young listeners with colourful designs and many add-ins.

6.5. Acceptance of limiting sound levels among the patrons at discothèques

According to a study by Germany's Federal Health Agency, 46% of Berlin discothèque patrons considered the music too loud and only 5% considered it too quiet. Thus, lowering the music level by about 10 dB will please discothèque patrons and will reduce the risk of hearing loss.

In 1997, the Independent Institute for Environmental Concerns asked 538 pupils from secondary schools in Berlin about their music habits. The result confirmed the assumption mentioned above; 48% of the interviewees said that discothèques in general are too loud and 92% would not oppose a lower sound level in discothèques (39).

Other investigations confirm these findings. Sixty-eight per cent of college students surveyed stated that live music events are too loud, with only 1% not considering the music loud enough (40). Broad acceptance of limiting sound levels in discothèques is reported in Switzerland, where sound limit values are prescribed by law in discothèques. After the legal measure was introduced, initial investigations show that about half the discothèque patrons still assess the sound levels as being too loud (41, 42).

These studies only asked for a general assessment of the volume in the discothèques attended. In a new study, subjective assessments were obtained from 133 secondary school pupils aged 16–19 years based on quantitative sound measurements in a discothèque at differing sound levels (43).

The test group heard typical discothèque music; each session lasted about 45 minutes and was played at different sound levels: 94, 101 and 92 dB(A), respectively. Most of these discothèque patrons would accept a sound level of about 95 dB(A). This means that discothèques limiting the sound levels would be unlikely to have fewer patrons.

In addition, the survey results show that even lower sound levels are requested in the relaxation areas. A similar investigation in a discothèque in Dresden, Germany, confirms the acceptance of a limit value of about 95 dB(A) (44, 45).

Investigations of music devices with an automatically limited sound level also show broad acceptance. The output signal was limited to about 94 dB(A). Only 4% of 422 pupils aged 16–24 years from schools in Berlin and Potsdam participating in a hearing experiment felt that the maximum volume was too quiet (46).

6.6. Laws prohibiting noise from music in Germany and other European countries

The current state of the investigation illustrates that preventing hearing impairment requires limiting sound levels from music. This applies both to portable music players and to music events such as discothèques or live concerts.

In 1996, France was the first country that passed a law stipulating a maximum output level of 100 dB (sound pressure level) for portable music players in addition to the warning. An automatic volume limiter system must be installed, and devices that do not meet these conditions are not allowed to be sold (47).

A Europe-wide arrangement for limiting the sound level of portable music players is expected in the near future. Activities for standardization at the European level have been started (48). This would limit the peak levels to 100 dB(A). Equivalent continuous sound levels of 90 dB(A) must not be exceeded (47).

Since 1 April 1996, Switzerland has regulated the protection of the public from health hazards arising through sound and laser beams at events. This regulation is based on the Environmental Protection Law and limits the average sound level for discothèques and music events to 93 dB(A). In exceptional circumstances, this may be increased through official permission to 100 dB(A) (with a peak sound level of 125 dB(A)). However, in this case the audience must be adequately informed about possible hearing impairment and protection against noise must be offered. The cantons are responsible for enforcement (49).

Sweden has a general recommendation that is considered as an official threshold value for intervention. The sound level in discothèques considered to risk hearing impairment is 100 dB(A) and the maximum sound level (sound pressure level, fast) is 115 dB(A) (50).

Occupational noise regulation in Denmark requires that personal ear protectors be offered at 80 dB(A), and ear protectors are compulsory at 85 dB(A).

Laws requiring noise abatement in Germany are concurrent legislation: the federal government and the *Länder* (federal states) are active in enforcing the law. If the federal law has loopholes or the *Länder* regulate this area, the *Länder* are requested to pass adequate laws.

Germany has no law stipulating unambiguously the maximum sound levels in discothèques in all *Länder*. Article 2 of the Constitution mandates the protection and the physical integrity of the citizens of Germany. Increased social protection is necessary for children (<18 years) and also for vulnerable people. According to ISO 1999 (19), 10% of the population is especially sensitive to loud noise. The current music sound levels are thus especially dangerous for such people.

Strict sound limit values, control measures and protection rules for occupational exposure are controlled, however, within the framework of occupational safety law. The accident prevention regulation for noise (51) from 1997 as well as European Union directive 86/188/EEC and workplace regulation obligates the employer to provide free personal ear protectors beginning at a sound level of 85 dB(A). Beginning at 90 dB(A), the use of earplugs is compulsory for the employees. In addition, the areas with a sound level exceeding 90 dB(A) must be labelled specifically as noise-intense areas.

The assessed sound level for broad-band noise corresponds to the average sound pressure level (energetic mean) resulting from the average over the entire work week for a 40-hour week.

Thus, the employees of a discothèque would have to be protected under occupational regulation against high sound levels. There is no obligatory arrangement, however, to avoid the risk of hearing impairment among the audience at music events.

In Germany, the laws and rights governing protection from noise (youth protection and the laws and regulations governing the catering trade) are under the jurisdiction of the *Länder*. Unfortunately, the *Länder* do not strictly enforce these regulations.

According to §1 of the Youth Protection Act, "... the responsible authorities have to take measures for warding off danger to physical well-being".

Instead, the German *Länder* have asked the federal government to free them from legal obligations in this area.

The Federal Immission Control Act (52) states that a legal basis for the determination of such threshold values could be the framework for regulation. It includes protecting people from hazards, annoyance and suffering. However, all other possibilities to promote insight and the voluntary measures resulting from that should be thoroughly exhausted.

The Federal Health Agency (53), the Federal Environment Agency (14, 54–58) and the German Medical Association (59, 60) recommend obligatory sound limit values in Germany.

Standard DIN 15905, part 5 has existed since 1989 (60). Following that DIN standard, the experts require that the average sound level be limited to 90–95 dB(A) with reference to the loudest audience area in the location of the event.

In addition, it is recommended ", ... that, for the protection of the listeners at public events (discothèques, open air events), the responsible person operating the technical devices – in particular, regulating the volume – be able to prove to the organiser of the event sufficient knowledge about the possible health risk caused by high sound pressure levels (>95 dB(A))" (50). That proof should be taken as a course.

Relevant occupational designations, such as "sound technician", "acoustic engineer" and "technical event specialist", should include education conveying this knowledge.

6.7. Legal situation in Germany

6.7.1. General

The present legal situation in Germany requires proving a relationship between cause and effect. This means that a discothèque or a concert patron must prove that irresponsible action by the organiser or the disk jockeys caused the hearing impairment.

Most admission tickets state that the organiser is not liable for any hearing impairment that may occur. Everyone is therefore responsible for protecting themselves.

Based on the state of science and technology, discothèque operators as well as organisers of concerts are recommended to limit the sound level in accordance with DIN 15905 (60) to prevent hearing impairment among patrons and to avoid liability suits (50).

Devices with headphones and other noise-producing products are subject to the regulations of the product safety law and the product liability law. These laws refer to technical standards to be considered by manufacturers and retailers to avoid liability for possible claims.

6.7.2. Legal provisions and rules for noise outside discothèques

The Technical Guidelines on Noise (TA-Lärm) comprise standard regulations for all of Germany. The Guidelines specify validated limit values to prevent harmful effects. The Guidelines include limit values for daytime (6 a.m. to 10 p.m.) and night-time (10 p.m. to 6 a.m.) for the different zones (determined through land-use planning).

Discothèques require official permits. The limit values outside buildings pursuant to the Guidelines are shown in Table 6.2.

Table 6.2. Limit values outside buildings in Germany pursuant to the Technical Guidelines on Noise

Industrial districts		70 dB(A)
Commercial districts		
	daytime	65 dB(A)
	night-time	50 dB(A)
Districts with mainly industrial use, rural areas and mixed-use areas		
	daytime	60 dB(A)
	night-time	45 dB(A)
General residential districts and small settlements		
	daytime	55 dB(A)
	night-time	40 dB(A)
Solely residential districts		
	daytime	50 dB(A)
	night time	35 dB(A)
Quiet districts (hospitals and care institutions)		
	daytime	45 dB(A)
	night-time	35 dB(A)

Single short-term noise peaks are not allowed to exceed the regulations by more than 30 dB(A) during the day and by not more than 20 dB(A) at night.

6.8. Overview of potential measures to reduce music sound levels

Administrative measures: determination of the maximum permissible sound pressure levels

- A law that determines a maximum sound level would impose clear limits. Compliance could be ensured through continuous sound level measurement or an integrating averaging sonometer (similar to a tachograph).

Technical measures and measures related to construction and room acoustics

- Limit the sound emission of music devices by electronic output limiting.
- Visualise the sound volume using level lights or similar means. For example, a green light means harmless sound levels, and a red light means dangerously high levels.
- Create quiet zones in which people can converse without raising their voice (<70 dB(A)).
- Locate the loudspeakers to ensure that no one can get too close to them, reducing exposure.
- The volume of music should not be increased during the evening.

Further measures

- Prescribe training for the operation of music devices to provide knowledge about the risk of hearing impairment from high sound pressure levels and about measures to protect the public from high sound levels.
- Carry out more education in schools.

6.9. Conclusions and perspectives

Children and young adults are highly exposed to noise because of trends in listening habits and in recreational activities. The increasing number of hearing-impaired adolescents must prompt politicians, educators and physicians to act (46).

Broad education is required, especially on music sound levels and other noise-producing leisure activities. People should be educated that permanent threshold shifts and continuing tinnitus are serious warning signals. This public education work must be carried out in cooperation with scientists and physicians, similar to other campaigns such as preventing HIV infection and reducing cigarette smoking. Schools must face the problem by integrating the topic of noise and hearing impairment into the usual content of such subjects as music or biology.

Noise should mainly be prevented from being emitted. When noise cannot be avoided or the noise is desired, personal ear protectors or appropriate breaks for recuperation should be required.

The general public is becoming increasingly aware of the problems associated with noise. Noise scientists have attempted to educate the public for years about the sound level of music. Unfortunately, no concrete results have yet been demonstrated.

One way to limit music sound levels comprises legal regulation. Another way is to make agreements with discothèque owners for voluntary limits.

Nevertheless, limiting noise levels in discothèques is a taboo topic in the music scene. This is why the public campaign must focus in an age-specific and modern way. The message should not be distributed with a strong moralistic undertone. Listening to quieter music must become modern, and a campaign must therefore seek to instil a positive image of quiet listeners.

However, data from Norway show that a good public relations campaign promotes acceptance and understanding among adolescents and that it changes behaviour concerning the sound level of music (61).

One possibility to demonstrate the acceptance of limiting sound levels would be to register and examine discothèques that voluntarily establish a sound level limit. This acceptance is an important argument for the introduction of laws and regulations that limit noise levels. These legislative measures are necessary to reduce the risk of hearing impairment in discothèques that do not limit the sound level.

6.10. Examples of good practices

6.10.1. Noise abatement in a discothèque

The preventive measure
In cooperation with the Institute for Labour Engineering of the Dresden University of Technology, the discothèque Dance Factory volunteered not to exceed 98 dB(A) in the Teeniedisco (held once weekly) for 6 months. This decrease in volume of about 10 dB(A) and modifying the frequency-response characteristics (reducing the especially dangerous frequencies by 6 dB) substantially reduces the risk of hearing impairment. This voluntary declaration of the discothèque applied initially from 22 April to 22 October 2001.

Characteristics and magnitude of the problem to be prevented
Music in discothèques and at concerts represents one kind of leisure noise that can induce lifelong hearing loss among young patrons. The Commission on Sociocusis (focusing on hearing loss from non-occupational noise exposure) of Germany's Federal Environment Agency explained in January 1995 that "according to contemporary scientific knowledge, listening to loud music risks permanently impairing hearing." (14).

Given their present music-listening habits, about 10–20% of adolescents would have slight but verifiable hearing loss of >10 dB at 3 kHz after only 10 years." (23)

The target population
The target population for the preventive measure includes 14- to 18-year-old patrons at discothèques in Dresden, Germany.

The setting
The project is currently being implemented at the discothèque Dance Factory in Dresden. It is planned to extend the project to more than one discothèque or club.

Description
This is a pilot project. Dance Factory agreed to limit the music sound level to 98 dB(A) once a week from 22 April to 22 October 2001.

Dance Factory is the only discothèque in Dresden in which the music sound levels are consciously lower than usual. This measure was initiated by the Institute for Labour Engineering of the Dresden University of Technology. The required technical equipment was donated by TBL, a technical consulting company in Dresden specializing in noise.

Documentation of the effect
Adolescent patrons at this discothèque are exposed to sound levels that are significantly lower than usual at discothèques. The usual sound levels at discothèques in Dresden are 105–110 dB(A). A decrease to 98 dB(A) is therefore a 10 dB reduction. This feels like half the noise level but reduces the noise exposure to one tenth of the starting level. This means that the adolescents could stay ten times longer in the discothèque and receive the same sound exposure as in a discothèque not limiting sound levels.

The Institute for Labour Engineering carried out preliminary studies and surveys concerning the acceptability of possible reductions in sound level and modification of the frequency-response characteristics (lowering the frequency range between 0.4 and 6 kHz, which is important for voice communication). The most important results of these preliminary investigations are as follows.

- The majority of the survey population said that 94 or 100 dB(A) is “just right” for dancing.
- One third of the trainees and two thirds of the pupils frequenting the discothèque think that sound levels of 106 dB(A) are too loud.
- Modifying the frequency-response characteristics did not influence the acceptable volume.
- The atmosphere is optimised by high volume. At the highest sound level of 106 dB(A), the atmosphere was considered the best.
- If people are aware of the danger of hearing impairment associated with high noise levels, sound levels of 94 dB(A) are also acceptable.

Positive side effects
The mass media reported about the project and helped to raise awareness of the problem among the public.

Adverse effects
No final conclusions can be drawn yet.

One negative effect could be a decline in the number of patrons at the particular discothèque, but the opposite could also happen.

Organization.
The Institute for Labour Engineering of the Dresden University of Technology initiated the project.

Funding.
The project did not receive any funding.

Ethical perspectives
Article 2 of Germany’s constitution mandates the protection and the physical integrity of the citizens in Germany. Extended social protection is necessary for children (<18 years) but also for highly vulnerable people. According to ISO 1999 (19), 5% of the population is especially sensitive to loud noise. The current music sound levels are considered especially dangerous for these people.

When the young discothèque patrons and the disc jockeys were made aware of the risk of hearing impairment associated with high sound levels, they accepted lower levels of 94 dB(A) according to the preliminary feasibility study.

Barrier.
The barriers comprise discothèque organisers and disk jockeys. They believe that the discothèque patrons prefer high volume. In addition, they are not informed about the possible dangers and therefore do not recognise the significance of the problem and their responsibility.
Another problem is that the discothèque owners are reluctant to publicise the current and previous sound levels in their discothèque since, as employers, they are responsible for the health of their employees. An official release of the sound level allows trade unions and employees with permanent hearing impairment to sue the employer.

Existing documentation
No report on the results has been prepared yet.

6.10.2. Art Instead of Noise

Project management: Independent Institute for Environmental Concerns

The preventive measure
The objective of the project is to enable adolescents to protect themselves effectively against the excessive sound levels at discothèques, live concerts and other music events. This requires developing modern earplugs for alternative protection.

Characteristics and magnitude of the problem to be prevented
Various manufacturers offer earplugs for industrial safety. The use of these products therefore focuses exclusively on fulfilling functional claims. Occasionally adolescents use these earplugs at live concerts or discothèques. Unfortunately, these adolescents represent a minority and need a certain amount of self-confidence since they have to fear isolation.

The acceptance of such earplugs will increase considerably if the earplugs protect hearing and yet show the humour, creativity, lifestyle and the hipness of the person wearing them.

In addition, the present marketing functions poorly. Earplugs are usually bought in a drugstore or at a home-improvement market, and this does not correspond to the real shopping habits of adolescents. The project is testing alternative distribution channels such as vending machines or sponsoring.

The target population
The target population includes adolescent concert and discothèque patrons.

The setting
The alternative earplugs are supposed to be offered everywhere at leisure events dominated by loud sound. The preferred areas of application are live concert events, music parades such as the Love Parade in Berlin and discothèques in general. Another possibility is events in motor sports.

Description
The only ways to comprehensively protect the hearing of all young patrons are limiting the sound level by law or regulation or getting the owners to voluntarily limit the sound level. However, these possibilities require substantial time to be realised, so that a satisfactory solution is not expected in the next 2 years.

The Art Instead of Noise project provides a third way: club owners and patrons can be convinced of the necessity of leaving the customary path with immoderately increasing sound volume, not with a moralistic undertone but with colourful and funny action.

Students at the Berlin Weissensee School of Art and Design designed Art Instead of Noise earplugs that can be accepted by the target age group as a fashion accessory and that protect hearing (Box 6.1).

Box 6.1. Selected proposals for earplug design from the students of the Berlin Weissensee School of Art and Design (Fig. 6.2)

Flowers are trendy!

You can see them on catwalks, raves or on the public places and streets. Flowers are absolutely trendy.

Flowers are used as accessories for fashion: real flowers as well as artificial ones. Decorating potentially less aesthetically pleasing earplugs with flowers is therefore a good idea. The decorative parts are fixed with a plug-in technique to stay on the ear plug. You can use optional silk flowers or stamped ones made from plastic.

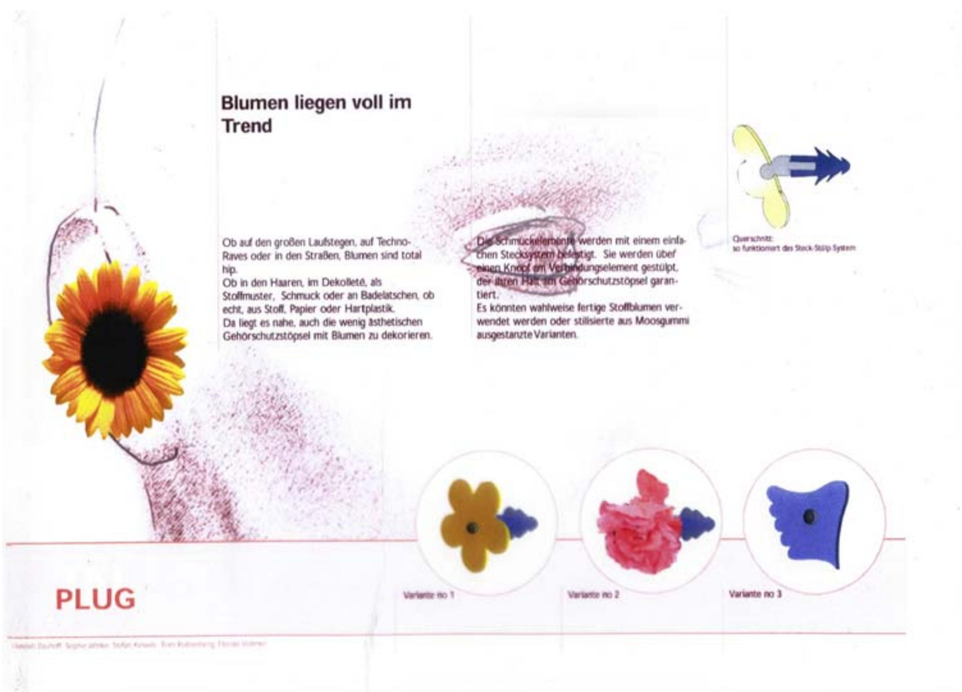
Delta plugs

Delta plugs are earplugs for the cool people. At parties, concerts, or raves, the delta plug hides the undecorative earplug. The delta plugs can be used with or without the insert part. There are different possibilities for distributing them: as a give-away together with concert tickets or at other events, for instance. The delta frames can hold all kinds of insert parts. You therefore have many options to change the look of the delta plugs.

Brands and earplugs

Today, young people define themselves more and more by external appearance, and brands play an important role. Companies owning these brands can therefore sponsor the earplugs and show their logo. A good place to display the logo is on a spherical part of the earplug remaining outside the ear.

Fig. 6.2. Selected earplugs from the students of the Berlin Weissensee School of Art and Design



Documentation of the effect
Earplugs usually reduce the sound level by about 30 dB. The risk of developing permanent hearing impairment induced by high sound levels was therefore mostly or entirely avoided.

A company was found that wants to produce such earplugs based on the ideas and the sketches of the students. The product has not yet been launched, so the effects cannot be documented yet.

Positive side effects
The mass media reported enthusiastically about this project. The public was confronted and informed about the project and the associated problems.

The questions: “What do you need ear protection for?”, “ Is it really so loud that you have to protect your ears?” or “Can loud music cause permanent hearing impairment?” touched the people. Thus, the public awareness of this problem increased. The project will have reached its objective when people start asking: “Why not just turn the music down; then we do not need any personal ear protectors?”.

Adverse effects
Since the project is still at an early stage, the possible negative effects can only be guessed at:

- The amount of trash at events may increase. However, this aspect is limited because the earplugs can be reused.
- The users of this product could become isolated within the peer group. To avoid this, a wide-ranging public campaign is planned.
- Purchasing the earplugs is an additional cost, but only one purchase is necessary because they can be reused. In addition, sponsors may distribute them free of charge.

Organization
The Independent Institute for Environmental Concerns initiated the project. The project work includes instructing the art students in layout and design, finding a company to produce the earplugs designed, conducting a public campaign and managing the product launch.

Funding
The project has not received funding. The students created the designs as part of a competition. The AOK Health Insurance Fund sponsored prizes valued at about EUR 200 for the four best designs.

Audia Akustik GmbH will produce the earplugs at its own expense.

Ethical perspectives
Introducing the alternative earplugs will protect adolescents against loud sound and raise their awareness of the problem.

Barriers
The barriers mainly comprise producing and introducing the new product. In addition, the consideration of patent protection plays an important role. Since the project has no external funding, the producing company bears the risk by itself. The product development is therefore uncertain.

Existing documentation
Since the product has not been marketed yet, no results can be documented. The mass media reacted very positively to the project. After the initial presentation, enquiries from the public emphasise the huge interest.

6.10.3. Research on adolescents' acceptance of limiting sound levels

Project management: Independent Institute for Environmental Concerns

The preventive measure
In a cross-sectional survey, 1674 pupils aged 10–19 years responded to a survey about their music-listening habits and the extent to which they would accept limiting the sound level in discothèques to 95 dB(A) (62).

Characteristics and magnitude of the problem to be prevented
Music in discothèques, clubs and concerts represents one kind of leisure noise that can cause lifelong hearing loss among young patrons. The Commission on Sociocusis (focusing on hearing loss from non-occupational noise exposure) of Germany's Federal Environment Agency explained in January 1995 that "according to contemporary scientific knowledge, listening to loud music risks permanently impairing hearing" (14).

Given current music-listening habits, about 10–20% of the adolescents would have slight but verifiable hearing loss of >10 dB at 3 kHz after only 10 years (23).

The target population
The target population of the project was pupils 10–19 years old from various primary and secondary schools as well as vocational schools in Berlin.

The setting
The project took place as an instructional module in these schools.

Description
The main objective of the empirical study was to determine the extent to which pupils 10–19 years old would accept limiting the sound levels at discothèques and concerts. Another objective was to find out the extent to which awareness can be increased by being instructed on the topic of hearing impairment caused by loud music.

The project researched the following questions.

- What is the state of knowledge on the topic of noise and hearing impairment in the different age groups and educational institutions?
- How well do adolescents of different ages accept limiting sound levels at discothèques and music events?
- How much do pupils know about personal ear protectors (such as earplugs) and how well do they accept such measures?
- What reasons do the pupils have to oppose limiting the sound levels and to oppose using personal ear protectors?
- Do such campaigns and projects change awareness measurably?
- In what grade are the pupils most responsive to the project? Do the pupils at the various types of schools differ in their response to the project?

The three questionnaires the pupils completed allowed a differentiated database to be built up on music listening and the possible acceptance of limiting sound levels in discothèques.

For that purpose, the pupils had to complete one questionnaire before and a second questionnaire after the instructional module (lasting two class periods) on the topic, to track possible changes in opinion caused by acquiring knowledge or discussing the topic.

Five to six weeks later, the pupils completed a third questionnaire to test the lasting effect.

The detailed activities of the project included:

- A questionnaire survey of the pupils on their music-listening habits and their acceptance of limiting sound levels at discothèques and other music events;
- Presenting the project to the pupils;
- Improving the pupils' knowledge on the topic of hearing impairment caused by loud music as well as hands-on experiences on the topic of noise by conducting experiments and exchanging ideas on the subject through discussion;
- A second questionnaire survey of the pupils on their acceptance of limiting sound levels at discothèques and other music events and of personal ear protectors; and
- Determining the lasting effect of the improved knowledge using a third questionnaire after about 5–6 weeks.

Documentation of the effect
According to the study, reducing the music sound level to 95 dB(A) would not adversely influence the acceptance and the visiting habits of a large majority of the pupils.

Only 28% of the adolescents in the initial survey said that they would object to limiting sound levels. The percentage opposing limiting sound levels declined to 21% after the instruction on problems of excessive noise and its potential dangers. Thus, improving pupils' knowledge supports the process of accepting limits on sound levels.

The educational project on the potential danger of noise increased the percentage of pupils indicating that they prefer limiting the sound level in discothèques from 21% to 34%.

Forty-two per cent of the pupils indicated that they would deal more carefully with temporary hearing loss and indefinable ear noises after the instruction. The changes in awareness continued even after 6 weeks.

Positive side effects
Parental permission was required for the pupils under 18 years old to participate in the project. For this reason, a letter that described the project and its objectives was sent to their parents. The positive reactions of the parents underscored the necessity of the measure, and in many cases the topic was discussed not only at school but also within the family. Further, the participating teachers were enthusiastic about the project. In addition, the teachers got everything they needed to enable them to create their own instructional modules about noise and hearing impairment in the future.

Adverse effects
No adverse effects are known so far.

Organization
The Independent Institute for Environmental Concerns initiated and carried out the project among 92 classes with 1808 pupils in Berlin; 1674 questionnaires were evaluated.

Funding
Germany's Federal Ministry of Health funded the project. The project lasted 8 months and cost about EUR 20,000.

Ethical perspectives
Pupils, parents, teachers and the school board were very open to the project. The preventive measure had no known ethical implications or risks.

Barriers
The study showed the importance of informing pupils about the potential risk of hearing impairment caused by loud music. It turned out that most pupils know little about this subject.

This topic urgently needs to be integrated into the school curriculum. The present teaching framework comprises a barrier. The topic is not yet obligatory. The biology or physics teacher can decide whether the topic should be taught or not. This is why raising the awareness of teachers on this topic and giving further training are important.

The existing documentation
The representative study showed that the pupils do not know enough about the potential risk of excessively loud music. Only 9% of the pupils were comprehensively informed about the possible risk of loud music. The project inspired 73% of the pupils to reconsider their leisure habits. This topic needs to be integrated into the teaching framework of primary and secondary schools.

The project showed that pupils change their habits as they learn more and that this change is long-lasting. The acceptance of measures limiting sound levels increased from 18% to 34% as a result of the project.

About half the adolescents do not care about possible limits on sound levels in discothèques. Other criteria, such as atmosphere, music style, meeting friends and entrance prices play a greater role.

Further, many adolescents request lower sound levels off the dance floor. The installation of quiet zones with sound levels below 70 dB(A) is recommended to the organisers of concerts and discothèque owners.

Virtually no adolescents accept the use of personal ear protectors at loud music events. More than 85% of the pupils surveyed indicated that they had never used such protectors yet. Only 1.4% of the participants indicated continuous or frequent use.

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7. Strategies for information and awareness raising activities

by Marie Louise Bistrup

We will never reach one another by shouting – only by listening to one another! (1)

The path from disseminating information to changing legislation or personal behaviour can be long and uphill. Disseminating information about the potential dangers of noise and acquiring knowledge about it are not automatically related. Information and awareness raising campaigns can and should vary in content and target groups depending on the specific situation.

7.1. Children's development stages and competence

Children spend much of their life in settings with varying levels of noise. Adults, in the role of parents, politicians, administrators, teachers and constructors, are responsible for developing or establishing the settings in which children spend their lives. Children can learn to take responsibility for the noise they make themselves, but they should not be made responsible for the circumstances leading to noise in children's settings. Teachers may complain that children are noisy, and parents may think that children need more discipline. Nevertheless, an underlying problem is high levels of background noise and poor acoustics, and improving these will create an environment conducive to lower overall noise levels.

Prevention of or protection against noise can be addressed at a personal and group level; at a discothèque; in the streets and in the home; and as social and public health problems that may require comprehensive planning and action at the community level.

Awareness-raising activities can address any level or event in the entire cycle or set of circumstances leading to noise or to the prevention of noise. The problem must be assessed specifically and the target group for the awareness-raising activity identified based on assessment of the needs, the objectives of the activity and means and methods. In short, the strategy of information and awareness raising campaigns should be sensitive and precise to encompass these aspects.

7.2. The approach of campaigns

Awareness-raising activities should be sensitive to age, gender and ethnic background, appeal to the target group or groups and be without moralistic overtones. Knowing the capabilities of the target group and having realistic information about their knowledge are important.

A strategy for raising children's awareness about sound and noise should build on children's stage of development, maturity and social, emotional and academic competence. Becoming aware of who makes noise and why or where noise comes from is an important step in educating children to begin to deal with noise. Children raised in noisy environments may need help in finding inner peace to be capable of requesting outer peace. Children can learn to become aware of "good" noise versus "bad" noise and to be aware of the noise they produce.

For children 1–6 years old, all media are relevant: books; pictures; cartoons; colouring sheets; posters; sound, music or noise on compact discs or tapes; videos; and computer games. Colours, rhymes, rhythms and repetition are part of the fun and increase learning. The material should appeal to the children's senses and emotions and relate to daily activity and experience. Examples are a coloured picture book for children published in Germany (2); colourful posters and colouring sheets from the National Clean Air Association in the United Kingdom; colourful posters and colouring sheets from the Dutch Hearing Foundation; and sound exercises on a compact disc included in a book (*Lärm und Gesundheit*) produced for teachers and schoolchildren by the Federal Centre for Health Education in Germany (3).

These principles also apply to schoolchildren, but they are capable of more abstract thinking and can take on more complex tasks, such as reading about the ears, noise and hearing, measuring noise and observing and noting noise sources. This applies to educational material about noise and health for grades 6–10 (see the example of good practice in section 7.9.2); information on posters and fact sheets about the functioning of the ear in relation to fireworks sent to all sixth-grade classes in Denmark before New Year's Eve 1999; and colourful and "hip" brochures for schoolchildren and young people about the ear, portable music players and hearing prepared by the Dutch Hearing Foundation (4–6). Children in this age group are interested in video and computer-based tasks, and interactive activities especially appeal to them.

One brochure prepared by the Dutch Hearing Foundation (4) targets children in primary schools, describing simply how the human ear works. It contains exercises showing the importance of hearing and warns gently about the hazards of portable music players and discothèques. Another brochure (5) targets children in secondary schools and includes assignments and exercises for the classroom or homework. It is very useful for thematic weeks. A brochure specifically on the hazards of portable music players (6) targets secondary-school children, suggesting ways to enjoy music without endangering hearing.

Adolescents should feel comfortable with the message being imparted, and the problem or area of concern should be addressed in their own language and style, with no moralistic overtones. Using the role models and idols of young people can be a clever way of arousing interest in the first place, such as when famous musicians admit that they have tinnitus and ask young people to take care of their ears (as in a video produced by Artists and Musicians against Tinnitus in Sweden, section 7.9.1.).

The Art Instead of Noise earplugs (see Chapter 6) comprise a good example of how information and awareness raising campaigns can give the target group a wider perspective. In another case, the earplugs are distributed to adolescents with the explanation that the loud music may hurt their ears and that the earplugs can prevent (some of) the harm. But as one young person said: Why not just turn down the music? Then we do not need the earplugs any more. The objectives of the campaign were to persuade young people to accept lower levels of music at discothèques, and this was achieved quite well through a campaign for using earplugs.

Parents and teachers want clear, scientifically based information and practical guidelines on how to deal with the area of concern. The tone of messages and information should be similar to good communication between partners. Avoiding professional jargon and a condescending tone of voice is crucial. It is also important not to instil (false) fears in people but to formulate relevant coping strategies and warnings based on facts and risk assessment. An example is the video in Sweden about noise from toys that encourages parents and child educators to listen to the noise emitted by toys before purchasing or giving toys to children (see the example of good practice in section 7.9.3).

A study in Sweden (7) showed that, if teachers in vocational settings use ear protectors, young people will wear them too. Nevertheless, the information material prepared about the necessity of wearing hearing protectors did not engage young people. The material was prepared for an experienced adult workforce and not for young trainees.

7.3. Interest groups

Many professional groups in such fields as paediatrics, audiology, acoustics, engineering and music are interested in sound and noise, and some are interested in the effects of noise and how to prevent noise. The *Manifesto for a better environment of sound* by the Royal Swedish Academy of Music (1) is a result of this kind of interest by a variety of professionals. The manifesto is brief, precise and comprehensive and gives guidance on a variety of noise-related concerns at the social and individual levels. The 33 points include promoting awareness about acute noise and sound problems as well as quiet, research and responsibility. The manifesto proposes action plans against noise, establishment of quiet areas, quiet offices, noise-free zones and noise banks: archives of sounds that are about to disappear. The final sentence of the manifesto says: “We will never reach one another by shouting – only by listening to one another!”.

Interest groups for and including patients or other people with impaired hearing have been established to promote and advocate solutions to meet the needs of members. Most countries have a national association for hearing-impaired people who promotes their interests. Some of these interest groups also take an interest in preventing noise-related hearing problems and are active in information and awareness raising campaigns, such as the Swedish Association of Hard of Hearing People, which initiated a nationwide campaign against tinnitus in 1999. In 1981, the National Association of Hearing Impaired in Denmark prepared a folder for young people about the dangers of loud rock music. In preparation for the fireworks to be launched on New Year’s Eve 1999–2000, the Association sent free earplugs to all sixth graders, together with a colourful poster and educational material for the teachers to use in class.

A special group is Artists and Musicians against Tinnitus (AMMOT), a voluntary association in Sweden whose main objective is to prevent hearing impairment caused by music. AMMOT’s campaign continues the general tinnitus campaign initiated by the

Swedish Association of Hard of Hearing People but focuses on young people at primary schools, festivals and discothèques. Some well-known Swedish music stars are members of AMMOT and can make a great impression on their audiences. AMMOT has produced a video film and poster that are designed to appeal to the target age group and have good results (see the good practice in section 7.9.1).

The Dutch Hearing Foundation was established in 1996 to promote hearing. It is not a patient organisation but carries out information and awareness raising campaigns and initiates research on noise and hearing. According to the Foundation, noise is sound that causes hearing impairment. The Foundation does not object to noise in general, but all statements are based on the levels or character of noise that can harm human hearing. The Foundation has prepared brochures for children (4–6). Each year it organises an Ear Week and lobbies members of parliament to promote the cause of preventing noise and protecting hearing.

7.4. Political campaigns and pressure groups

Groups of citizens may think that society does not address the problem of noise satisfactorily and establish interest or pressure groups. Examples include groups formed near airports scheduled to expand and international nongovernmental organisations such as the European Environment Bureau, which collaborated in preparing a briefing document on the problems and perspectives of preventing noise at the European level (8).

The Norwegian Association against Noise was founded in 1963 as an independent organisation seeking to promote the interests of the people annoyed by noise. The aim is to inform about and monitor noise problems in society and to work to reduce them. The Association:

- Monitors and follows up specific noise issues and cases;
- Disseminates information and takes initiatives towards the government, politicians and private and public services about the best solutions to prevent noise; and
- Produces and distributes information on noise abatement.

The Association prepared a number of comments to the draft European Union directive on the assessment and management of environmental noise (9) and warned that it should not become a “paper tiger” (10). If the directive is adopted, it should be followed up by a strong action plan. The Association has proposed looking to Switzerland’s policy on noise as a model, including an action plan for “cleaning up” noise in existing areas with defined time limits for clean-up to meet the set standards, and linked to a complete financial plan, according to the polluter-pays principle.

7.5. Noise Awareness Day

April 24 is International Noise Awareness Day. Noise Awareness Day is an activity indicating the need for understanding and preventing noise at all levels. It is being celebrated internationally for the seventh time in 2002, predominantly in the United States but also in several European countries. Noise Awareness Day in Norway was organised for the first time on 12 April 2000; 15 nongovernmental organisations with different approaches to noise joined the celebration. The Norwegian Association against Noise took the initiative, and the celebration became an opportunity to put noise on the agenda of other organisations.

Because 24 April usually falls around Easter time when offices are closed and people may be away on vacation, the United Kingdom National Society for Clean Air and Environmental Protection has decided to find another date for Noise Action Day. In 2000, the theme of Noise Action Day was Rural Tranquillity – Valuing the Sound of Silence. Finding peace and quiet in the countryside risks becoming a distant memory across much of the United Kingdom without firm government action to value and protect rural tranquillity. Noise Action Day was celebrated in the United Kingdom on 6 June in 2001 and will be on 22 May in 2002.

The Society is the only national nongovernmental organisation in the United Kingdom that addresses noise as a social problem. The Society has prepared educational material for teachers and children and prepares an annual noise survey involving environmental health officers to describe the sources of noise about which the general public usually complains. Neighbourhood noise seems to be the most important noise problem for the general public, whereas noise at schools seems to be important for politicians. The Society prepared information and educational material in relation to Noise Action Day, and the effect is being assessed by local and central government agencies, which are noting how many times the material has been cited in the mass media (interview, Mary Stevens).

7.6. Public-sector initiatives

Public agencies carry out official information and awareness raising campaigns, such as the educational material for teachers of grades 4–10 prepared by the Federal Centre for Health Education in Germany. Another example is collaboration between public and semi-public agencies; Denmark's Ministry of Social Affairs, Ministry of Education and the National Association of Local Authorities in Denmark prepared three booklets for staff in day-care centres (11–13). These booklets are primarily based on examples described in Project Being Heard (mentioned in section 4.11.1) and propose technical, practical and educational measures for preventing noise and for creatively using outdoor facilities.

Occupational health legislation in Denmark does not include children, but it is assumed that some guidelines prepared, for example, for the social and health sectors may also benefit children. Guidelines from 2000 advise on measures to reduce noise (14).

7.7. Politicians

Some members of Denmark's Folketing (parliament) noted that not much was generally known about noise levels and the effects of noise in society at large. The Folketing therefore asked the Danish Board of Technology to prepare a consensus conference on noise. Two panels were established, a panel of citizens and a panel of experts, including a couple of international experts. During a period of months, the citizens' panel formulated questions to the experts, and a consensus meeting was held on 12–13 and 15 May 2001 based on the answers from the experts. Only one member of the Folketing participated in the meeting. The material from the consensus meeting was published on the Internet (www.teknologiraadet.dk), and the report from the entire activity was sent to all participants. A brief summary in English was also published (15).

7.8. Conclusions about strategies for raising awareness

The following media have been used in the information and awareness raising campaigns identified in this project:

- Written material such as brochures, booklets, picture books, documents and popular magazines;
- Media with human voices, music and sound;
- Pictures and moving pictures, films, videos, television and interactive computer-games;
- The Internet: information for professionals and other adults, parents, interest groups and children and music for downloading;
- Questionnaires;
- Statements made by prominent people who have great appeal to young people; and
- Being present with props and promotional educational material at festivals and discothèques.

Because videos, computer games and films include sound, they are good media to illustrate sound and noise situations, in addition to pictures and the written word. The videos on dangerous toys and on tinnitus mentioned in this project have very vivid and loud examples of noise, with great effects on the viewers.

For the purposes of promoting health, three phases for carrying out awareness-raising activities have been identified (16):

- Raising awareness: through media, promotion and signage (signs and symbols);
- Education: through educational programmes targeting specific groups as well as educational resources; and
- Structural change: creating healthy environments by implementing policy and changing the environment.

The examples of awareness-raising activities included in this report touch all three of these phases, and point to a continuum of activities and projects that can be undertaken for problems or objectives that have been identified. The medium, the message and the attitudes in information and awareness raising campaigns should be finely tuned to appeal to the defined target group.

7.9. Examples of good practices

This section describes in detail the organisation, experience and evaluation of three information and awareness raising campaigns identified by interviews that were chosen as examples of good practice:

- AMMOT's continuation of the tinnitus campaign in Sweden in 2000;
- Educational material for raising awareness in schools in Germany in 2000; and
- A video about dangerous toys in Sweden in 2000.

7.9.1. AMMOT's tinnitus campaign in Sweden in 2000

The awareness-raising campaign

The tinnitus campaign is an awareness-raising campaign aimed at protecting young people against tinnitus. Sweden designated 1999 as a year to focus on tinnitus. The tinnitus group at the Swedish Association of Hard of Hearing People disseminated information and organised events. In addition, seminars were held and a brochure and a video were produced.

The tinnitus campaign by Artists and Musicians against Tinnitus (AMMOT) aims at making the fight against tinnitus a permanent campaign among young people.

Characteristics and magnitude of the problem

Tinnitus is a hearing disorder manifested as a ringing in the ear, although there is no exterior source of noise, and only the person with tinnitus can hear the sound. The sound can be heard as one tone or more tones, as ringing or buzzing, whistling, a whisper or scratching sounds.

Tinnitus is a serious hearing disorder. There are methods that claim to cure tinnitus or ameliorate the symptoms but little evidence to prove or disprove the claims. These methods may be very costly, not be very accessible and have frequent remission.

Tinnitus has increased among young people. Kajsa-Mia Holgers of Sahlgrenska Hospital in Göteborg estimates that about 200,000 people in Sweden have tinnitus. Holgers found that 16% of children 9–16 years old at a school in Göteborg had tinnitus; girls had both a higher prevalence and more severe symptoms than did boys (17, 18).

The socioeconomic burden mainly comprises reduced quality of life for the people with tinnitus. Tinnitus can lead to social isolation and stress and can affect the choice of occupation.

Target population

Children listening to music through portable music players and computer and television games are risk groups, but they can control the volume of the sound. Young people attending concerts and discothèques cannot individually control the volume. Earplugs can reduce the impact of the sound. The quality of earplugs varies, and the most inexpensive earplugs are often the most effective but also reduce the fidelity of the sound. Teenagers may be vain and may not want to use earplugs until a critical mass of their peers start to do so because of campaigns.

Hearing-impaired children are vulnerable because they depend on low background noise levels to ensure a high signal-to-noise ratio. Children in general are vulnerable in situations in which they cannot control the course and loudness of the sound.

Teenagers are a vulnerable group, as they attend discothèques, concerts and festivals. They may not know about the dangers of noise, may not wear earplugs and may not, individually or collectively, demand that the sound levels at the concerts be reduced.

Professional and amateur musicians are exposed for many hours at a time and are often reluctant to wear earplugs as this reduces their ability to hear what they are playing.

Setting for the campaign
The tinnitus campaign was carried out at primary and secondary schools and at concerts and festivals. Earplugs can be used in any setting.

Description of the campaign
The mission of AMMOT is to prevent tinnitus and hearing impairment by disseminating information, distributing earplugs and carrying out projects that aim at increasing the acceptance of reducing the levels of noise in society, especially music. More and more people have tinnitus as a result of exposure to high sound levels. The average sound levels at concerts in Sweden have increased by 40 dB since the 1960s. AMMOT thinks that everybody has the right to know how to avoid tinnitus and hearing impairment so that people can enjoy the music they love throughout life.

The objective was to inform about tinnitus and on how to avoid it, teaching young people to avoid exposure to loud noise and to prepare them to accept lower sound levels at concerts. The strategy was:

- To distribute a video film and information material to schools;
- To distribute inexpensive earplugs for free at concerts and music festivals;
- To sell high-quality earplugs at concerts and music festivals;
- To show the video film at concerts and music festivals;
- To distribute the video film and information material to the mass media; and
- To make presentations about tinnitus at festivals and at schools.

A 15-minute video film about music and tinnitus was produced and a poster and a brochure (*Wear ear condoms so you don't get hearing aids*, text in Swedish). The film has a fresh approach and features important Swedish musicians and artists disclosing the fact that they have tinnitus and explaining the cause. Presentations were made at three major music festivals in Sweden and at ten schools. The video film is sold for EUR 10.50, and 3000 copies have been sold so far.

A large transparent plastic container with electric tubes blinking in different colours to indicate the sound level contained the free earplugs. More than 100,000 free foam earplugs were distributed and 1400 articles about tinnitus were printed in the general and professional mass media. Money for tinnitus research was collected by selling high-quality earplugs (often called musicians' earplugs). The funds are distributed through the Swedish Association of Hard of Hearing People.

Documentation of effect of the preventive measure
Demoskop, a market research company in Sweden, evaluated the tinnitus campaign. Demoskop found that 32% of the general population knew about tinnitus before the campaign versus 70% afterwards.

AMMOT evaluated the effect of the video film by distributing a questionnaire to 230 pupils in fifth grade (11–12 years old). Five questions were asked before and after the video film was shown.

Table 7.1 Responses to a questionnaire survey of 230 fifth graders in Sweden on the effect of a video film on tinnitus (%)

Question	Correct replies before watching the video film	Correct replies after watching the video film
What is tinnitus?	83	97
How does a person get tinnitus?	88	99
What is a decibel?	29	70
Where are the hair cells located?	30	92
Where can you buy earplugs?	48	85

Source: AMMOT

The schoolchildren were also asked to rate their impression of the video: 74% considered it to be good, very good, interesting, educational or useful, 5% fair, less than 1% poor and 20% did not respond.

Positive side effects
Preventing tinnitus can also prevent other types of hearing impairment.

Adverse effects
No adverse effects were observed.

Organisation
AMMOT was established in 1999. AMMOT is a not-for-profit voluntary association of lovers of music, artists, musicians, disc jockeys, sound technicians and others interested in tinnitus and music. Several members are hearing-impaired.

Cost
The campaign costs about EUR 37,500 and producing the video film about EUR 37,500.

Ethical perspectives
No negative ethical implications or effects have been found.

Barriers
Young people may find wearing earplugs unattractive and think that they do not look cool. Musicians and concert promoters may think that attempting to reduce sound levels infringes artistic expression.

Existing documentation
Evaluation of initiatives to raise awareness about the hazards of noise and about the potential preventive measures is important. The level of pupils' knowledge was evaluated before and after a session in a school class. It has not been evaluated whether the exposure to hazardous noise levels generally declined or whether the campaign reduced the number of young people acquiring tinnitus.

Contact information
The review is based on an interview on 23 April 2001 with
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7.9.2. Educational material for raising awareness in schools in Germany

The Federal Centre for Health Education produces health promotion material on noise and preventing noise. The main material produced for schoolchildren and teachers is a publication on noise and health from 1997 (*Lärm und Gesundheit*) (19). The publication includes a compact disc with various listening examples, sounds and experiments. The publication is aimed at pupils in grades 5–10 (aged 10–16 years).

Two copies of the publication were sent to all 17,000 secondary schools in Germany in 1997. In addition, universities and teacher training schools received the publication. Initially, 37,000 of the 72,000 copies printed were sent to schools and teacher training institutions. Teachers often want their own copy and order extra copies. From November 1997 to May 2001, 16,500 additional copies were sent upon request. Dissemination has been successful, and requests are still coming in.

The teachers requesting this publication are mostly from the natural sciences. The publication is often used in situations in which children can choose between different subjects, and teachers can include noise as a topic in such subjects as biology or physics. Teachers can choose noise and health as an important topic, and the publication is very popular.

Aims of the material
The publication was developed for teachers to help them prepare the discussions with schoolchildren. The aim of the publication is to make children aware of the problem of noise. Children should be aware of the noise that affects them and learn that silence is the opposite of noise. They should learn to find inner peace in order to establish outer peace: quiet is part of the quality of life. The material has many suggestions and assignments. Teachers can ask pupils to carry out experiments, including how to work with different sounds, background sounds, noise from traffic and music. The pupils can produce sounds and experience the different effects of noise.

Experiments with noise
The compact disc contains many listening sessions, and the publication offers an excellent opportunity for teachers to discuss with pupils. Assignments are suggested that pupils can do in groups or alone. For example, pupils can go outside and measure the noise in residential areas with considerable road traffic and areas with little traffic. The schools may have noise-measuring equipment, the municipal environmental department may lease it to schools, or nongovernmental organisations may lease the measuring equipment.

Through such experiments, pupils realise that they can do something about noise. Pupils can become skilled in handling noise problems and may approach the municipal administration or politicians and organize demonstrations and other events to lobby for reductions in noise in specific places.

The Federal Centre for Health Education will launch an innovative idea, as it has developed software that allows noise measurements to be loaded directly onto the school computer.

A book for children 6–10 years old
The Federal Centre for Health Education has also prepared material on noise and health for younger children in grades 1–4, with information, education and assignments that lead to experience with sound and noise (20). The messages are mainly that listening habits should be changed, that ears should be protected and that listening to loud music is an important hazard for young people.

The book is called *Lärm und Gesundheit* like the first book but is aimed at children in primary school, ages 6–10 years. Involving the parents when their children start discussing noise in school is important. The new book will be distributed to all 18,500 primary schools in Germany, two for each school, and 60,000 copies will be printed.

Both books, for grades 1–4 and 5–10, are supported by federal funds. Education about noise is accepted at the federal level but not specially promoted.

Changes in behaviour
Awareness about noise often leads to changes in behaviour. The younger pupils start to appreciate quiet when they become quieter. The older children cherish quiet but seem to carry on as usual. When pupils become concerned about noise, they often become concerned about the noise they make themselves. It is important that children experience this themselves and especially the difference between noise and quiet. The younger pupils may choose to make noise elsewhere.

Schoolyards differ from school to school. Some schools attempt to improve the role of the schools in promoting health by such measures as establishing quiet areas and loud areas. Schoolyards have been improved at an estimated one-third of primary schools. Some large schoolyards have been divided into smaller sections; asphalt and cement yards have been broken up and turned into green spaces; and bushes and flowers have been planted.

Awareness-raising material for parents
Parents should be able to support the education about noise of their primary school children. To encourage and enable parents to discuss noise and its effects with their children, a leaflet for parents (*Zu viel für die Ohren*) (21) has been prepared.

When children start school, the public health offices and the school physicians carry out a health examination including hearing tests. The brochures for parents were sent to the school physicians, who are supposed to distribute the brochure to parents in connection with the health examination. A total of 250,000 copies were printed, and 92,400 copies were distributed from January to May 2001.

The main message to parents is that noise is dangerous. Being loud is also a pleasure for children, and quiet is necessary for everyone. The material warns about noise from toys and gives shopping tips for portable music players. The advice to parents is to buy equipment with an automatic volume limiter system. Only one manufacturer seems to have an automatic volume limiter system so far, but it is hoped that more will follow.

Different approaches for different age groups
Educational material must respect and reflect the differences between pupils 6–10 years old and those 10–16 years old. Teachers can take a more responsible and technical approach towards the older pupils, whereas education for the younger pupils should be based more on personal experience and emotions. Measuring equipment can be bought or leased so that the older pupils can measure noise.

In the younger classes, the teacher can describe phenomena and discuss the feelings and the well-being of good sounds and of quiet. A good exercise is the listening walk. One pupil is blindfolded, and all sound appears much louder to this pupil, because vision filters the perception of sounds. When this filter is taken away, sounds appear more overwhelming. Thus, the children experience the ability of the ear to hear. The mechanism is not explained but experienced.

More teacher training is needed: too few teachers have comprehensive expertise. In addition, disc jockeys should be trained and educated and perhaps be licensed.

Organisation and adaptability of the campaign
Health education is an important arena for preventing noise. The noise material has received positive reactions not just from teachers and schools but also from the ministries responsible for culture of various *Länder* (federal states). The Federal Health Education Centre has partners in each *Land* and meets twice each year to discuss what colleagues think about education on noise to further promote awareness.

At the political level, some *Länder* have required schools to teach this topic. For example, Baden-Württemberg (in 1997) and Bavaria (in 1999) emphasised that including noise in the school curricula was important.

The schools in Baden-Württemberg were in close contact with the public health offices. Physicians came to the schools supporting the project, sometimes by teaching the teachers and sometimes teaching the pupils directly.

The effort to increase awareness of noise in schools is seen as a successful preventive measure that could be adapted to other European countries. In Switzerland, the Swiss Federal Office of Public Health has produced a media kit for schools on a campaign to prevent the harmful effects of noise called the "Whole Ear" (22).

The German Network of Health Promoting Schools may be a potential partner, but the Network does not currently consider noise an important topic.

Contact information
The review is based on an interview on 17 May 2001 with
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Federal Centre for Health Education,
Cologne,
Germany.

7.9.3. Video about dangerous toys, Sweden

The Stockholm Association of Hard of Hearing People has produced a video warning about the great danger to hearing posed by the noise level of toys with support from the Swedish Consumer Agency. The video was produced in 1997. The aim is to disseminate information about children's hearing to everyone involved with children, such as day-care centres, playgroups, schools and parents. The video was also shown on Swedish television, reaching 1 million viewers. In late 1997, parts of the video were shown as public service announcements on television (23)

Contact information
This brief review is based on an interview with
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and
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8. Further research on preventing the adverse effects of noise on children

This chapter builds on input from three sources that have identified the lack of or gaps in research:

- Reviews of literature and research;
- The partners and consultants in the project; and
- Key people interviewed in the project.

This report focuses on studies and examples of the effects of measures to prevent noise. The potential negative and positive effects of various types of intervention have been researched insufficiently. This project has found some research themes related to the effects of noise, and these are included in the list of proposals for future research. *Health effects of noise on children and the perception of the risk of noise* (1) also lists identified gaps and proposals for research on the health effects of noise.

8.1 Assessing the magnitude of the problem of noise in children's settings

One objective of the interviews in this project was to determine the scope of the problem of noise by asking how many children are exposed to noise levels potentially harmful to their health and well-being. The answers were sporadic or anecdotal; systematically collecting data or assessing how many children are exposed to noise in children's settings in the countries involved in this study has not been possible. A major priority is thus to create and collect data on how many children are exposed to potentially harmful noise, in different settings in Europe.

The WHO *Guidelines for community noise* (2) recommends acceptable noise levels that can be used to determine the settings to be considered noisy (see Chapter 2). The WHO guideline values would be useful in determining how many children are at risk of non-auditory health effects from noise exposure in settings such as day-care centres and in schools.

8.2 Proposals for new research

The proposals cover general themes and themes or research questions related to the three settings for children focused on by this project, and related to information and awareness raising efforts and to vulnerable children.

Other aspects that require further research or investigation include:

- Policy on preventing noise in children's settings;
- Experiments and development projects;

- Training of professionals;
- Factors influencing and barriers to manufacturing less noisy products, such as toys and machines, and sound equipment with automatic volume limiter systems.

8.3 Identified gaps in research

8.3.1 General themes

Interventions to reduce noise need to be evaluated using well-controlled large-scale studies to determine the effect on children based on numerous performance and health effects associated with noise exposure. Studies are required to provide more precise insight into the mechanisms that underlie the effects of noise on children. Some research themes are general and apply to children of all ages:

- The effects of chronic and acute exposure to noise on children's sleep;
- The effects of chronic and acute noise exposure on children's mental health;
- The protective and restorative effects on children's health of establishing and ensuring access to quiet zones in different settings;
- Will more silent environments/settings promote more silent speech and calmer behaviour among children?
- The effects on children's health of exposure to ultrasound, low-frequency sound (infrasound) and ventilation sound; and
- Improved identification of which groups of children are especially vulnerable to noise.

Other research questions of general interest include:

- How much noise exposure (including time and level of noise) does it take to destroy the hair cells in the inner ear among children of different ages?
- What period of quiet is needed to restore hearing after noise exposure (including time and level of noise) among children of different ages?
- Quantification of the influence on children's well-being and speech intelligibility of reducing noise compared to reducing reverberation time?

8.3.2 Day-care settings

The following themes need more research in relation to day-care centres:

- The effects on children's sleep of intervention in day-care centres to reduce chronic and acute noise exposure;
- The effects of noise on children in outdoor spaces in day-care centres (playgrounds);
- The effects of open-plan day-care centres on noise level and exposure; and
- The effects of the number of children in rooms or groups on noise levels (crowding).

8.3.3 Schools

The following themes need more research in relation to schools:

- The effects of open-plan schools on noise level and exposure;
- Effective interventions to reduce noise in open-plan schools;
- The effects on children of noise in outdoor spaces in schools, including schoolyards, playgrounds and sports fields;
- The effects of different kinds of music on children doing homework; and
- The effects of number of children in classes on noise levels (crowding).

Children doing homework while listening to music. Children increasingly listen to music while doing homework. Does classical music open the senses and help children perceive what they read? Does rhythmic music establish a good background for learning? What kinds of background music (noise) are detrimental to children doing what kind of homework?

8.3.4 Discothèques and festivals etc.

The following themes need more research in relation to discothèques and festivals and other leisure activities:

- Screening or testing for tinnitus: Testing for temporary threshold shift is the best predictor for long-term hearing problems;
- Estimating the proportion of young people who have tinnitus;
- The noise levels of adolescents' leisure activities, such as fitness and exercise clubs and the effects of this noise;
- The effects of reducing the noise levels of adolescents' leisure activities, such as fitness and exercise clubs;
- The effects on children and the youth of noise from video and computer games in homes, computer game stores and video arcades;
- The noise levels in cinemas during both child films and films for the youth (and adults); and
- The effects on children and the youth of high noise levels in cinemas.

8.3.5 Information and awareness raising initiatives

Awareness-raising among children can consist of experimental and educational projects. For example, Artists and Musicians against Tinnitus (AMMOT), a voluntary association in Sweden, has initiated two school projects on listening to what you are hearing and an educational project on sound and hearing. Such projects need funding and schools to collaborate with and would probably have a greater impact on children by being carried out in several countries simultaneously.

A suggestion is that a city map for the Internet is constructed, where all discos are entered and identified by levels of noise permitted in the discotheques. This is supposed to enable the youth to consciously select discos where music is less loud, and it should be evaluated for effect on the choice of discos among the youth.

Awareness-raising and educational projects need to be evaluated for both short and long term effects and developed into good examples and serve as inspiration for others.

8.3.6 Vulnerable children

The following themes need more research in relation to the effects of noise and effectively preventing and reducing noise among vulnerable groups of children:

- Children with impaired vision or hearing, including congenital problems and acquired impairment;
- The effects of the acoustic climate on visually impaired children;
- Psychoacoustic perception by blind people;
- Children speaking two or more languages, especially those whose dominant language differs from the dominant language in society;
- Children with special learning needs;
- Children with learning or social problems;
- Children who are already exposed to other social and environmental stress factors;
- Determining whether the effects of noise are greater among younger or older children; and
- Determining whether the effects of noise are greater among girls or boys.

Some blind people develop their other senses more to compensate for the loss of sight. This can be used in a positive way by constructing walls and floors of different kinds of materials that reflect sound differently and thus can be used to indicate rooms with different functions. Even children with severely impaired hearing may sense different acoustic climates, and experiments and research can help to find the optimal acoustic climate for these children.

More research on psychoacoustics can improve understanding of the capacity of blind children for deep perception. Good acoustic conditions can support and enhance such intrinsic skills among blind people. Auralisation seems useful as a means to train blind people, including children, to use new buildings, such as a new school. Auralisation can simulate the reflections of rooms (walls, floors and ceilings) and constructs soundscapes that blind people can learn to recognise so that they will be prepared and capable of using the new setting.

8.3.7 Policy

Some innovative projects are being developed at the administrative level or among interest organisations to carry out policy on preventing noise. Other policy initiatives, however, require political commitment and support. The following are examples of such new projects and policy initiatives.

Projects to develop environmental labelling
Pilot projects for labelling environmental quality indoors and outdoors, including noise and acoustics, could be carried out for schools and kindergartens as a tool for creating environmentally healthy settings for children. Such projects can be evaluated, and good examples may inspire potential follow-up through legislation and guidelines for mandatory environmental labelling, including the sound classification of buildings used for children.

Development of new methods
New digital methods open new avenues for rapid communication about noise and acoustic problems. An example is using digitalized photos of classrooms when installing acoustic tiles. The acoustic engineer can remotely assist the workers by recommending where in the classroom the tiles should be installed, because they can simultaneously see the classroom on the screen.

The Internet could increasingly be used to present good examples of preventing noise in children's settings. Many public agencies and nongovernmental organisations already use the Internet for communication and could present guidelines and illustrated examples of how to prevent noise. An example in England is the inspection of standards of schools by the Office for Standards in Education that is available on the Internet (www.ofsted.gov.uk).

The results of old measurements of noise and reverberation time can be analysed and take on a new dimension. An example is more than 400 noise measurements in classrooms in 19 municipalities over a long period of time conducted by an acoustic engineer in Sweden to indicate the need for noise reduction and acoustic treatment, mainly because hearing-impaired children were to be integrated into the schools. Measurements of reverberation time and noise can be repeated after intervention to determine the acoustic improvement; interviews with teachers and children can be conducted to assess the level of satisfaction with intervention. The analysis of old measurements may reveal the historical development of noise in classrooms.

Methods of measuring noise could be refined by being complemented with accurate observations and description of the specific sources of noise (a passing tooting train, a child screaming or a chair scrambling?), so that intervention can be targeted the observed noise levels and peaks.

Auralisation is the process of rendering audible, by physical or mathematical modelling, the sound field of a source in a space, in such a way as to simulate the binaural listening experience at a given position in the modelled space. This has potential to be developed into a practical tool for engineers, architects and contractors. Proposals for different acoustic measures can be tested theoretically by applying auralisation methods to different room layouts and interventions. Auralisation requires complex computer programs but is an easily understood and democratic tool.

Training of professionals
Physicians are normally trained in the functioning of the ear, and day-care and school teachers are trained in understanding and reacting to child development. Nevertheless, most professions are trained in none or few aspects related to children and preventing noise, and probably less in acoustics and the sources and settings of noise exposure.

Training architects and engineers is important in achieving a high level of awareness about good design and acoustic quality in settings for children. Methods for developing good acoustics should be made available to developers in the form of guidelines or fact sheets.

Production of sound equipment
Methods of persuading manufacturers of music equipment and toys to make quieter products should be studied. One brand of sound system advertises a set of loudspeakers that can produce up to 170 dB(A). The catchwords for the loudspeakers are "Disturb the peace". Such advertisements may support the stance that loud noise is acceptable or even positive.

8.4 Setting priorities among research themes

This project has agreed on the following criteria for setting priorities among the research themes related to preventing the adverse effects of noise on children:

- Gaps in research; and
- Evaluating interventions that will benefit as many children as possible.

Important research themes or questions based on these criteria are:

- Evaluating the effectiveness of intervention to reduce noise in open-plan day-care centres and schools;
- Evaluating the protective and restorative effects on children's health of establishing and ensuring access to quiet zones;
- Evaluating the effects on children of noise in outdoor areas (schoolyards, playgrounds and sports fields);
- Determining the period of quiet needed to restore hearing after noise exposure (including time and level of noise) among children of different ages;
- Assessing the effects of the number of children in rooms or classes on noise (crowding); and
- Assessing the effects on children of noise from video and computer games in homes, computer game stores and video arcades.

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Annex 3. Summary of the non-auditory effects of noise on children's health

by Staffan Hygge

This chapter summarises two chapters in: Bistrup ML, ed. *Health effects of noise on children and perception of the risk of noise* (European Commission Grant Agreement No. SI2.143779 (99CVF2-601) as amended by recent research. For more detail and more complete references, see the report.

Noise settings

Many tools, equipment and toys emit equivalent and maximum noise levels high enough to induce temporary or permanent hearing loss. However, since accurate statistics do not exist on how much time children spend in various environments, their weekly or monthly noise doses and the percentage of children exposed to unacceptable noise levels cannot be estimated accurately. Nevertheless, certain types of equipment in certain environments are more hazardous than others to children's health and well-being. For instance, power drills and motor saws used by adults in the home close to children and toy guns, often used close to the ear, may harm hearing. In particular, toys and firecrackers with explosive, impulse sounds are harmful since the duration of the impulse is long enough to harm hair cells in the inner ear, but not long enough to cause a corresponding annoyance reaction in the brain.

Tables 1.1 and 1.2 show the noise levels for some tools and toys presenting the greatest risk for hearing impairment.

Table 1.1. Noise level of various tools and equipment

Type of machine	Noise level (dB(A))
Power drill	100
Motorised saw	102

Source: Ministry of the Environment, Denmark (1)

Table 1.2. Peak noise level for selected toys at a distance of 2.5 cm

Toy	Peak noise level (dB(A))
Police machine gun	110
Cap gun (toy pistol) fired with caps	134
Cap gun fired without caps	114
007 cap pistol with caps	127
007 cap pistol without caps	118

Source: National Consumer Agency of Denmark (2)

Outdoor concerts and indoor discothèques also threaten children's hearing. Many European countries restrict the maximum noise levels allowed in such settings. But these restrictions are not always respected: the noise levels close to the loudspeakers still exceed the limit values, and temporary and permanent hearing threshold shifts and tinnitus are expected in the future among the people exposed to this noise.

For outdoor concerts and indoor discothèques, listening to sound is the preferred activity, and the sound does not primarily interfere with competing, more desirable activities. The same is largely true for noisy games and noisy toys. The noise is part of the fun, and it does not block other goal-directed behaviour. In educational settings, such as schools, one priority is verbal communication, which is easily masked by or blocked by competing noise, both from other people in the same or adjoining rooms, from installations in the building and from exterior transport noise.

Children, hearing-impaired people, elderly people and people whose first language differs from the predominant language need a better signal-to-noise ratio than do other people: 15–20 dB or more may be required to understand verbal communication. To achieve this, the background noise levels in classrooms, for example, should not exceed 25–28 dB(A) L_{eq}. This is expensive to achieve by retrofitting school buildings that were not initially designed to meet this standard.

A reverberation time of 0.8 seconds or somewhat shorter in a classroom usually provides acceptably low interference from echoes. A reverberation time of about 0.5 seconds is preferable for children and elderly people or when good speech understanding is needed.

Classrooms and teaching settings seldom provide good listening conditions in terms of signal-to-noise ratio and reverberation time. According to Picard & Bradley (3):

> Quite surprisingly, poor classroom acoustics seem to be the prevailing condition for both normal-hearing and hearing-impaired students. In particular, reported ambient A–weighted noise levels are approximately 5–35 dB above values currently agreed upon for optimal understanding by normal-hearing children and 17–32 dB too high for hearing-impaired children.

Improving room acoustics in public classrooms and other teaching facilities and finding ways to reduce the transport noise around schools are good general ways to improve children’s listening environments. Limiting the peak noise levels and the time of exposure among children at leisure time is more difficult, but more could be done to reduce the impulse noise levels from toys.

Extra precaution may be needed in day-care settings with high outdoor noise levels and high indoor levels because of noisy activities, shouting and screaming. In such environments there is a risk of vicious circles of indoor noise levels increasing even further to overcome masking from all the other sounds.

Effects of noise

General effects

The effects of noise on attention, cognition and communication can usually be detected at lower noise levels than the effects on hearing or physiology. This implies that whenever physiological reactions (such as blood pressure, neuroendocrines or hearing impairment) are reliably detected, effects on attention, cognition and communication are already present. Thus, a good research strategy is to begin looking for effects on attention, cognition and communication and to establish safe levels.

Foetuses and babies

It cannot be excluded but does not seem likely that environmental noise causes foetal abnormalities. However, studies of the effect of environmental noise on the foetus have been hampered by serious limitations in methods, both in the assessment of noise exposure and effects and failure to control for known determinants of the effects under investigation. The same applies to studies of preterm and full-term babies.

Preterm babies must cope with their environment with immature organ systems. Since the auditory, visual and central nervous systems are the last systems to mature, these last stages occur, in part, during the time the preterm child is in an incubator or neonatal intensive care unit. Measurements in such units have shown equivalent sound levels of 60–90 dB(A) and peak levels up to 120 dB(A). Although not much research has been done on how these noise levels affect pre-term babies' hearing, sleep, physiological reactions, auditory and emotional development, the noise levels by themselves are high enough to be a warning.

Traffic noise sources

Similar to adults, noise from transport is the most prevalent source of noise for children in schools and at leisure activities. Also, as for adults, noise at the same L_{eq} level from different transport sources differs in the annoyance caused. Train noise is perceived as less burdensome than noise from road traffic, which in turn is less annoying than aircraft noise. This difference in annoyance also produces differential effects on learning and memory (4). Aircraft noise harms long-term memory more than does road-traffic noise, which in turn is worse than train noise.

Noise stress

All the components of the stress response among preschool children and schoolchildren, including physiology, attention, communication, cognition and motivation, are of interest for noise-abatement policies. There is no consensus on how these different response systems interact in forming a general stress response or in what sequence the different responses arise. It is not known whether physiological reactions, such as increased stress hormone levels, precede changes in attention and cognition, or whether the physiological reactions result from inability to cope or adapt cognitively to noise. Since children as well as adults probably vary considerably individually in the extent to which the various response systems contribute to a general stress response to noise, the whole spectrum of noise reactions, from physiological reactions to more perceptual, cognitive and motivational reactions, must be considered.

Blood pressure – neuroendocrines

Both cross-sectional and longitudinal, prospective studies provide evidence that exposure to noise increases systolic and diastolic blood pressure. A study in Munich (5, 6) found that chronic noise exposure increased epinephrine and norepinephrine levels. These results are part of a pattern of a more general stress response among children to their noisy environment, especially at school. However, the studies of physiological and psychological variables have never reported about the correlation between the two types of effect measured.

Reading

Chronic noise exposure adversely affects reading. About 20 studies have found that chronic noise exposure delays acquisition of reading skills among young children (7). There are no contradictory findings, and the few null results are probably caused by methodological problems. In addition, several other aspects of the research on noise and reading render definitive conclusions. The data include prospective, longitudinal effects (8), evidence of a dose–response function and results showing that sound attenuation interventions in three different situations reduced or eliminated the negative effects of noise on reading (9, 10). Most of these studies controlled well for socioeconomic status and hearing ability. Some of the studies have carefully assessed children under quiet conditions, indicating that the effects of noise are caused by chronic exposure rather than acute conditions during the testing phase.

Studies of acute noise on reading performance are much more mixed, which can partly be attributed to the briefer duration of exposure. Studies have not shown a reliable effect of acute noise on math performance, although it can be discussed whether the tests in question assessed mathematical rather than computational skills.

Memory

There are fewer studies of the effects of noise on other cognitive processes among children than on reading. The most ubiquitous memory effects occur for complex, semantic material (4). Several studies of both chronic (5, 8, 11, 12) and acute noise (4) have found that exposure to aircraft noise adversely affects long-term memory for complex, difficult material. Hygge (4) replicated the adverse effects of simulated aircraft noise at both 66 and 55 dB(A) L_{eq}. He also showed that the adverse memory effects of aircraft noise and road-traffic noise exceed those caused by train noise at a comparable intensity.

Chronic noise exposure does not seem to impair long-term recall of visual material and recognition memory.

Children's incidental memory for visual material may be adversely affected by chronic noise exposure, although this effect has not always been replicated. Short-term memory does not appear to be sensitive to chronic noise unless it is sufficiently loud to mask the encoding of stimuli.

Attention

Several studies have examined possible links between noise exposure and attentional deficits among young children, with mixed results. Studies in schools exposed to aircraft or train noise reveal that noise levels may be sufficiently loud and intrusive to distract children, according to observers (13).

Several investigators have uncovered relationships between chronic noise exposure and poorer visual search performance under controlled, quiet testing conditions. Haines et al. (11, 12) reported similar results with an auditory sustained attention task analogous to those found with a series of clerical tasks, including proofreading. No general adverse effects of chronic noise on visual search tasks have been reported, but the duration of exposure to chronic noise may play some role for visual attention (7). Fourth- and fifth-grade children performed better on a visual search task during acute noise exposure if they had been exposed to chronic noise for a maximum of 2 years, whereas the opposite pattern occurred for children chronically exposed to noise for more than 4 years.

Findings for auditory discrimination suggest varying resistance to auditory distraction as a function of personal history with ambient noise, indicating that children chronically exposed to noise have poorer auditory discrimination and ability to detect differences between words that sound similar. Noise-related deficits in auditory discrimination might be caused by children learning to ignore auditory stimuli (blocking out distraction) as a way to cope with chronic noise. In addition, young children chronically exposed to noise are less adept at picking out the most optimum signal-to-noise ratio when meaningful stimuli are presented among a background of broadband continuous noise. However, poorer auditory discrimination because of chronic noise exposure does not seem to mediate noise effects on memory (8).

Although noise adversely affects the long-term memory of a text, neither acute noise exposure (4, 14) nor chronic noise exposure (8) affected attention, as measured by the number of text pages read.

Acute noise impaired another measure of attention, the search-and-memory task (lines of random letters, preceded by one set of five target letters, the occurrences of which are to be identified in the line) (14). However, the performance on this attention task did not mediate and was not correlated with long-term memory performance on a reading task (14). For chronic noise exposure, there is no mediation from noise by attention to memory (8).

Motivation

Laboratory studies and several field studies indicate that children chronically exposed to noise are less motivated when placed in achievement situations in which task performance requires persistence (7, 9). Chronic noise has also been associated with deficits on a standardised index of frustration tolerance, and infants reared in noisier homes manifest lower mastery scores on a standardised developmental test. A second index of motivation, refraining from making a choice, is also affected by chronic noise exposure. Following a set of experimental procedures in quiet conditions, children chronically exposed to noise were more likely to relinquish choice over a reward to an experimenter compared with their well-matched quiet counterparts.

Chatter and irrelevant speech

Pupils often complain about chatter and irrelevant speech by other pupils as noise sources. Studies of irrelevant speech and short-term memory justify such complaints, showing that both meaningful and meaningless speech cause pronounced impairment, especially on memory tasks with a serial component (15, 16). These findings have recently (14) been extended to the long-term memory of a text, with the magnitude of the effect of the irrelevant speech noise being equal to that of road-traffic noise of the same L_{eq} and intermittency pattern. Since the number of studies on irrelevant speech and long-term memory is limited, speculating as to whether the noise effects on long-term memory are routed along the same kinds of processes as for short-term memory is premature. It is also too early to try to evaluate the relative debilitating effects of exterior road-traffic noise versus noise from chatter and speech inside a classroom.

Indirect noise effects

In addition to the direct effects of noise in interfering with communication and cognition, a high noise level in schools and day-care centres also leads to raised voices and resulting strain on the larynx and vocal cords. Vocal abuse may occur when children talk too long, too loudly and using too much effort. The noise level in schools and day-care centres is often so high that children scream to make themselves heard above the other children (17), thereby putting themselves at the risk of developing lasting voice and speech problems.

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Annex 4. Format for structured interview on preventing or reducing noise in primary schools

1. Policy

1. What is the national policy or environmental goal for background noise in primary schools?

2. Standards

Are legislation, standards and guidelines the same for public as well as private schools in your country?

1. What is the national standard for maximum background noise in a classroom?
2. What is the national standard for maximum indoor noise in a classroom?
3. What is the national standard for maximum background noise for outdoor areas in schools?
4. What percentage of primary schools in your country experience noise problems according to the above-mentioned standards etc.?
5. Are current legislation, standards and guidelines satisfactory with respect to avoiding problems caused by noise?
6. (If building legislation and standards were implemented and respected what % of schools would have noise problems?)

3. Seriousness of the problem

a. What % of children is enrolled in public schools?
b. What % of children is enrolled in private schools?
c. What % of schools is suffering noise problems? Public? Private?
d. What % of children is suffering noise problems? Public? Private?

4. Interventions

In order to carry out a systematic review of interventions please fill out this structured table.

Please give examples of interventions aimed at reducing background noise, indoor noise and outdoor noise in primary schools. The interventions should be evaluated or otherwise assessed as having been effective for the situation they were targeted at.

	Problem to be addressed	Regulations	Physical measures to reduce noise	Information	Other measures
a. Children's activities indoors					
b. Adults' (teachers', parents') activities indoors					
c. Installations in the classroom or in the school					
d. Equipment in the classroom or in the school					
e. Road traffic in the surroundings of the school					
f. Railways in the surroundings of the school					
g. Air traffic in the surroundings of the school					
h. Please give examples of establishment of zones free of man-made noise at schools					

(Please enter keywords in the table, maximum 5 words per cell)

5. Effective preventive measures

Please give examples of successful and effective preventive measures in relation to the above-mentioned sources.

1. Type of prevention
2. Who is leading the prevention
3. Method of measuring the effect
4. Results of the evaluation
5. Positive effects of an intervention
6. Negative effects of an intervention
7. Costs

6. Adaptability

Which successful preventive measures in schools in your country do you think could be adapted to other European countries?

7. Further measures

In your country, what plans are there for further measures to prevent adverse effects of noise on children in schools?

Please mention small as well as large-scale initiatives, including initiatives where the main focus may not be noise abatement, but where noise reduction will be a side effect.

a. National action plans?
b. Regional action plans?
c. Local action plans?

Ethical considerations

8. Contact information

Please list contact persons and institutions that can give supplementary information on this theme

(Name, address, phone, fax, e-mail)

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Annex 5. A framework for reviewing preventive measures

By Lis Keiding, Staff Specialist, National Institute of Public Health, Denmark

The elements of a description of examples on prevention are:

1. The preventive measure (briefly)
2. Characteristics and magnitude of the problem to be prevented
   - The type and seriousness of the problem
   - An estimate of the percentage of people at risk in relevant age groups
   - The type and estimated magnitude of the socioeconomic burden caused by the problem
3. The target population for the preventive measure
   - Age or high-risk groups
   - Vulnerable groups
4. The setting for the preventive measure
   - Examples: home, day-care centre, nursing home, school, club, hospital, family doctor, other type of primary health care
5. Description of the preventive measure
   - Description of the practical way of implementing the preventive measure
6. Documentation of the effect of the preventive measure
   - Summary of the most significant effects of the measure with references for the sources of information
7. Positive side effects of the preventive measure
8. Adverse effects of the preventive measure
9. Organisation
10. Economic analysis (if available)
    - Account of the costs of the preventive measure
    - Summary of assessment of costs (money) and benefits (health in a broad sense)
11. Ethical perspectives
    - Description of acceptability, potential ethical implications and risks
12. Barriers to the preventive measure
    - Brief account of barriers, such as fear, costs or risks
13. About the existing documentation
    - Account of scientific evidence for the effect of the preventive measure (as far as it is available)
14. Index
    - Listing of key words for indexing
15. References
16. Links
17. Reviewer and date the review was completed

Annex 6. Acoustics in open-plan schools and day-care centres – problems and opportunities

by Claus Møller Petersen

Introduction

Schools with open or partial open plans are coming into fashion again in Denmark. There are two reasons for this. The Act on Public Primary and Lower Secondary Education (1) has introduced new forms of education. In addition, a current architectural trend has already promoted open-plan arrangements in many office buildings in Denmark.

Most open-plan schools built during the 1960s in Denmark had poor acoustics. Acoustic problems were so severe that almost no open-plan schools have been built. The rules on acoustics introduced in the Danish Building Regulations in the 1970s were not the reason that the number of open-plan schools was dramatically reduced for a long period.

Open plans involve sound propagating almost unimpeded between the teaching groups. This causes tremendous noise problems, making it almost impossible to understand what is being said. Each individual group has little influence on the overall noise level, and this is extremely disturbing. From an acoustic point of view, open-plan schools are not recommended.

Large open rooms in day-care centres in Denmark (including centres serving children of various age ranges from 0 to 12 years or more) are often poor acoustically and therefore noisy, and acoustics is a problem when these rooms are used for several purposes. These rooms require acoustic improvement to reduce the effects of noise.

Legal stipulations

The Danish Building Regulations (2) state the following in Section 9.3.3, subsection 5.

> In classrooms equipped for teaching several classes or groups, the surfaces of the room, including the ceiling, floor and wall areas, must be built using materials with an equivalent absorption area[4] averaging at least 0.9 times the floor space in the frequency range between 125 and 2000 Hz. Deviations from the average value must not exceed 0.2 times the floor space in any frequency range.

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[4] The equivalent absorption area measures the total quantity of sound-absorbing surfaces in the room. It is derived by multiplying the area of a surface by the acoustic absorption coefficient α. Hard, shiny or massive surfaces reflect the noise (α= 0), whereas soft, porous surfaces absorb the noise (α=1). Hard surfaces and large room volumes create long reverberation times, whereas soft surfaces and small volumes create short reverberation times. The acoustics of a room can be described by the reverberation time or by the equivalent absorption area. A room with a large equivalent absorption area has a short reverberation time.

This stipulation means that the surfaces of a room must be chosen so that they absorb a substantial part of the noise, reducing the reverberation time.

If open-plan schools were built using current building traditions, the flooring would be hard and noise-reflecting (linoleum, wood and the like). The ceilings would have maximum noise-absorbing qualities (an acoustic ceiling – porous material, perhaps covered with acoustic tiles). Finally, the furniture would be relatively poor at absorbing sound. As the teaching rooms in open-plan schools have little wall area, using the walls as noise-absorbing surfaces is often not an option. Nevertheless, the covering of all surfaces close to the users of the rooms is important and should be included in the acoustic regulations.

The Danish Building Regulations (2) include provisions on impact sound pressure levels and total noise levels. According to Section 9.3.2, floors and stairways must be constructed so that the impact level does not exceed 63 dB(A) in the classroom. In classrooms designated for teaching music and woodwork, floors must be constructed so that the impact level does not exceed 53 dB(A) in the surrounding classrooms.

Section 9.3.4 stipulates that the noise level from technical installations in classrooms must not exceed 35 dB(A). Section 9.4 stipulates that the average reverberation time in living-rooms in day-care centres must not exceed 0.6 seconds in the frequency range between 125 and 2000 Hz.

Hoffmeyer & Petersen (3) present recent recommendations on reverberation times reducing this to 0.4 seconds in after-school and preschool day-care centres.

Few studies have examined the acoustics of schools within the last decade in Sweden, Norway, Finland, Germany, the Netherlands, the United Kingdom and the United States (4). Specific stipulations on the acoustics of open-plan schools have not been found in these countries.

Acoustics in large rooms – objective characteristics

The reverberation time and noise level are often used to describe the acoustics of a room. In general, when the source of sound is not too close, the shorter the reverberation time, the lower the noise level in a given room with given sources of sound.

These acoustic concepts are mostly used to describe the acoustic work environment in workplaces with the purpose of limiting the noise exposure of personnel. Nevertheless, these concepts are inadequate for classrooms and must be bolstered by concepts describing the speech intelligibility in the room. Large rooms, such as those in open-plan schools, should also include the parameter of how well the propagation of sound between teaching groups is reduced.

Speech intelligibility
The speech transmission index (STI) is an objective measurable value describing the speech intelligibility in a room. The STI considers both the reverberation time and the sound intensity from a person speaking adjusted for the background noise level in a room (signal-to-noise ratio). The STI value varies between 0 and 1. An STI value of 0 means no speech intelligibility, and a value of 1 means optimum speech intelligibility.

Suppressing sound propagation and enhancing the privacy of teaching groups
The suppression of sound propagation through a room is measured objectively by determining the sound attenuation between two teaching groups or attenuation according to the doubling of the distance (5).

Privacy in a teaching group requires a low share of unwanted acoustic information. This also means poor intelligibility between the teaching groups (a low STI value) combined with substantial suppression of sound propagation.

The acoustic environment – subjective experiences
In open plans, the pupils are distracted and the teachers resigned because of the massive acoustic problems, including (6):

- Excessive noise levels compared with vocal intensity;
- Too much irrelevant information;
- The lack of privacy – poor acoustic separation between groups; and
- Excessive reverberation time.

The lack of acoustic privacy may be regarded as far eclipses the potential advantages of open plans.

Another aspect of the acoustic environment in open-plan schools is the importance of the users' behaviour. The noise is controlled by self-discipline and peer pressure (6).

In partial open-plan schools, both pupils and adult users progressively adapt their behaviour to become quieter to accommodate to the acoustic conditions. The great challenge is to find the right balance between acoustics and practicable accommodation.

The physical environment and education in schools – visual and acoustic openness
The Act on Public Primary and Lower Secondary Education (1) stipulates that the school must create an environment conducive to experience, motivation and concentration. Schools must be functional and educational to promote both varied forms of education and the peace to allow immersion and concentration. This includes both thematic weeks in which many pupils gather across several grade levels and group work with a few specific pupils.

Many new schools have walls with substantial glass to provide experiences through visual openness: following what is happening in other groups. Because glass is an acoustically hard and reflective material, it should be used carefully with a limited area to avoid poor acoustics. Glass in walls creates visual openness but also distracts children who are studying, working or reading. Glass in children's working areas should begin above the height of the children's eyes. Finally, the Danish Building Regulations require avoiding the risk of personal injury if glass is used in walls.

Open-plan schools were previously built with few internal walls. Glass walls integrate acoustic insulation and visual openness. The right balance must be found between visual openness, sound insulation and room acoustics (reverberation time).

Flexibility in open-plan schools and day-care centres
The noise and activity levels of younger and older pupils differ substantially (6). The young pupils tend to be noisier than the older ones. Just as the pedagogical framework must vary and be broad, the physical environment should be flexible: adapted to the pupils' development and the planned use of the room.

Schools and day-care centres should have rooms suitable for both vivid and noisy activities as well as rooms for quiet activities and activities requiring concentration. This is also valid for day-care centres.

Variation and flexibility in open-plan schools is therefore also important to suppress noise propagation between teaching groups and to optimise the acoustics within each teaching group.

Options for ensuring optimum acoustics
Acoustic options in partial open-plan schools and large rooms in day-care centres include:

- Limiting the room height: less than 3.5 metres to ensure the optimum functioning of acoustic ceilings, but large height is important in ensuring optimal indoor climate using natural ventilation;
- Using very effective sound-absorbing surfaces: the acoustic absorption coefficient must be optimal, $\alpha > 0.95$ or sound absorption class A as defined in ISO 11654 (7):
  – In ceilings
  – On walls, in alcoves, in panel walls and on the front edges of balconies
  – In internal room dividers
  – In furnishing and pinboards that can be dismantled;
- Constructing walls with sound-absorbing surfaces if the length or width of the room is less than 10–15 metres;
- Installing variable noise absorbents, such as noise-absorbent curtains mounted in front of hard walls;
- Maximizing the distance between teaching groups;
- Acoustically separating (partly by glass) quiet and noisy teaching groups;

- Installing mobile wall elements (which can be partly glass) or acoustic walls that fit tightly to the floor and are tall enough to interrupt the direct line of sight;
- Placing glass in walls at a level that minimises unwanted visual disturbance;
- Protecting openings in walls (without doors) by installing screens or semi-walls in maze-like configurations to prevent noise from entering through the opening;
- Ensuring that the wall behind the teacher (often a blackboard) prevents the transmission of sound from areas outside the classroom and reflects internal sound towards the teacher's area to provide the teacher with sound reflection, making it easier to talk without straining the voice;
- Installing sound-absorbing acoustic tiles on the wall in the back of the teaching area (8);
- Installing flooring such as linoleum on cork, thick wooden floors or partly carpets to reduce impact noise and drum noise (wall-to-wall carpets are not currently used in Denmark);
- Ensuring adequate sound insulation from environmental sound (such as traffic noise);
- Managing the noise originating from technical installations and traffic; and
- Using computer modelling to calculate detailed acoustics of existing rooms and of potential future rooms with specific characteristics.

The conclusion is that open-plan schools are not recommended from the viewpoint of acoustics.

Acoustic design criteria – a checklist
The following design criteria should be observed to obtain the best possible acoustics.

Partly open-plan schools
- The reverberation time should be short, less than 0.3–0.4 seconds.
- The acoustic attenuation between two teaching groups should be at least 15–20 dB. This should also apply between teaching groups and corridors (using detachable screens, mobile walls or built-in walls with glass).
- The propagation should be attenuated by 5–8 dB for each time the distance doubles.
- Within teaching groups, the STI should be greater than 0.6. The STI between teaching groups should be less than 0.2; this can best be checked by using a computer model of room acoustics.

Partly open-plan schools and day-care centres
- The noise level from technical installations should not exceed 35 dB(A).
- Noise from environmental sources should not exceed 35 dB(A).
- Flooring must be selected based on its capacity to avoid disturbing impact noise (in rooms underneath, normally $L'_{n,w} < 63$ dB) or disturbing drum noise from footsteps in the same room.

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Annex 7. Primary schools in Sweden

by Marie Louise Bistrup

Occupational health

The Work Environment Act in Sweden makes the employer responsible for ensuring that employees do not get ill from the work environment. Since 1991, the Act has covered students from seventh grade and up. Since 2000, occupational health legislation has covered all children in day care, preschool and primary school and people employed in these settings (1). Students in seventh grade and up can select up to two safety delegates per grade.

The Work Environment Act, Chapter 6, §17–18 (1), specifies children's opportunities to engage in workplace safety work:

> Section 17
>
> Persons undergoing training or education shall be given the opportunity, by the mandator of the training or education, of taking part in safety activities at the worksite through student safety delegates, if this is reasonable having regard to the nature of the training or education and its duration.
>
> Student participation, however, does not apply to pupils below grade 7 of compulsory school or the corresponding youth education.
>
> Section 18
>
> Student safety delegates are appointed by the students. The educational mandator shall ensure that the student safety delegates receive the training and leave of absence needed for their duties.
>
> Student safety delegates are entitled to the information necessary for the discharge of their duties, except for information concerning matters which are confidential in accordance with Chapter 7, Section 13, subsection 1. Concerning information classified as secret in public activities, the Secrecy Act (1980:100) shall apply.

Acoustic regulation

The building regulations established by Sweden's National Board of Housing, Building and Planning (2) began to include acoustic regulations for educational environments in 1999. These regulations contain binding regulations and general recommendations. Noise from permanent installations inside and outside school buildings and noise from traffic should not exceed 30 dB(A). According to the National Board of Health and Welfare (3), children with special needs are entitled to sound levels that do not exceed 25 dB(A) in educational environments.

A good acoustic environment includes silence and no noise from chairs scraping, desks, machines, ventilation, traffic and adjacent rooms (4). Acoustics should correspond with the visual impression of the room, which should neither be over-insulated nor have an excessive reverberation time. The handbook *Att se, höras och andas i skolan* has been included in the building regulations as guidelines since 1 January 1999.

Reverberation time in educational environments must not exceed 0.6 seconds in each octave band from 125 to 4000 Hz. The acoustic quality is also described by the application 90% absorption class B.

The weighted apparent sound reduction index (R'_w) for walls should be at least 48 dB for foldable walls or walls with doors. The maximum level for impact sound ($L'_{n,w}$) is 68 dB.

Noise levels in school
The indoor environment was surveyed in ten primary schools in Umeå, Sweden. A report (5) describes the problems found during the investigation and concludes that the background noise in the classrooms mainly stems from ventilation systems. Samples of noise measurement showed noise levels above the recommendations of the National Board of Health and Welfare (5).

Children with special needs
In general, children with impaired hearing are integrated into the ordinary school system. The municipalities and schools are responsible for regulating classroom acoustics to meet the special needs of children with impaired hearing. Magne Sjöström inspects schools in the Municipality of Lund, measures noise and reverberation time and prepares a note for the school indicating the acoustic characteristics that the classroom must meet to accommodate the needs of the child. The school must then find a way of meeting the acoustic standards. Too often the standard is not good enough, as is shown in Table 1.

Table 1. Results of acoustic measurement in 27 classrooms in schools in the Municipality of Lund, Skåne County, Sweden, 2000

	Number of classrooms
Long reverberation time	12
Loud noise	17
Inadequate insulation against airborne noise	18
Inadequate general lighting of classroom	2
No comments	2

Source: interview with Magne Sjöström

Method for organizing measures to improve acoustic quality
Magne Sjöström developed an efficient method for communicating and collaborating about organizing the improvement of acoustics in specific classrooms. The noise level and the reverberation time are measured and digital pictures of the room taken. This allows the stakeholders of classroom acoustics to communicate about the specific design and plans for a room without being present in the room. For example, when acoustic tiles are to be mounted, the technician can, when in doubt,

communicate with an acoustic engineer by telephone, examine electronic pictures of the classroom and receive guidance on how to proceed.

How not to achieve a good acoustic environment
Some new schools are built with noise-promoting materials such as ceramic tiles on the floor, concrete walls or a pyramid-shaped, tall glass roof that lets in daylight but has a hard surface and makes noise when rain falls. A wooden floor on an uninsulated surface contributes to poor acoustics, and even wood floors can conduct noise. A chair scraping on the floor was identified as the source of 102 dB. The chairs are made of bent steel or metal tubes, with a wooden seat.

According to the building regulations, noise from ventilation should not exceed 30 dB(A) in specific classrooms in a newly built school. According to Magne Sjöström, one newly built classroom had noise levels of 40–45 dB(A) from ventilation. Much would be achieved if building regulations and guidelines were complied with (interview Magne Sjöström).

Checklist for a good acoustic environment
Pernilla Sandberg, an acoustic engineer at the Department of Audiology of Sahlgrenska University Hospital in Göteborg, Sweden stated that the municipalities do not comply with the building regulations and has developed a checklist for assessing the acoustic quality of a school (6).

- Make an inventory of noise levels from ventilation systems and exhaust outlets.
- Let the occupational health services measure reverberation time and speech perception within classrooms.
- Install insulating seals around doors; this will reduce noise from adjacent rooms and will prevent slamming of doors.
- Mount foam or rubber pads under the lids of school desks.
- Place a used tennis ball with a hole in it on the leg of each chair.
- Use curtains, drapes and other thick material that absorbs sound to create a softer environment.
- Use upholstered furniture; it is more comfortable to sit on and can also absorb sound.

Stress among children in schools
In February 2001, Sweden's ombudsperson Louise Sylwander said (7):

> Most children with psychosomatic problems are not doing poorly at home. This happens in children's activities outside the home that are not organized with the well-being of the child in mind. There are depressing and dirty environments, depressing environments in corridors and in schoolyards that are not stimulating, large cafeterias, no opportunities for relaxing, resting and reflecting or sitting in smaller groups or meeting the adults in a situation of communication and reflection. This can cause psychosomatic symptoms with headache, tiredness and stomachache and lead to anxiety and depression in the long term. In most cases it is not the children who are ill, it is the surrounding environments that are not designed with the children's needs in mind. An even worse situation is the schools' reception for the youngest students, who are less well equipped for unhealthy environments.

A report on children's stress in school (7) emphasizes that children's first contacts with working life are developed in schools. Children's experience with the occupational environment in schools is part of the foundation on which they base their rights and duties as adults in the workforce. Large classrooms are often boring and sound levels therefore become high, which leads to health problems for the pupils.

Children need relaxed and tranquil moments during meals in schools. But canteens are often not properly dimensioned for the number of students attending them; there are lines, crowding, pushing, screaming and high noise levels, and many pupils experience this as a problem. Many children indicate that the library is the best place to be: "It is quiet there".

Many children experience headache during school, and children with recurring headaches indicate that noisy and stressful environments are the triggering factors. Children consider the classrooms depressing, dirty and noisy.

In general, the environments make demands that do not correspond to the capabilities of the students, and the opportunities provided by the environment do not correspond to student's needs. Researchers have concluded that (7):

> school seems to lead to types of behaviour that develop into negative health trends.... It is a serious problem that children and youth in activities outside the home, such as in schools, are exposed to health risks in terms of noise, high sound levels, abusive behaviour, large classes and few personnel. Many reports and studies have shown that children and youth are exposed to unreasonable stress levels in canteens and in classrooms during breaks and that psychosomatic symptoms during recent years have increased and are continuing to increase.

Preventing unhealthy stress in school requires creating space and time for reflection, rest, meeting informally and communication.

Awareness-raising campaign among teachers

The Swedish Teachers' Union has prepared two brochures in Swedish for teachers as tools for increasing the teachers' expertise in addressing noise and voice problems at schools.

One brochure describes what teachers can do to create a better acoustic environment and protect hearing. The other brochure describes what teachers can do to protect their most important tool, the voice. The brochures aim at promoting self-help and list educational as well as technical solutions to apply in schools. The brochures are sent to all professional ombudspersons, headmasters and student safety delegates. The Swedish Teachers' Union is planning to place the two brochures on its Web site and thus make the guides accessible to all members.

The brochures recommend the following criteria for a room with good acoustic quality.

- It is easy to understand what teachers and students say.
- Permanent installations such as ventilation systems should not make unnecessary noise (<30 dB).
- No sound should be heard from adjacent rooms or from traffic.
- The reverberation time of the room should be short, no more than 0.3–0.5 seconds, and should not contain echo or resonance that would distort people's voice.
- The rooms should not be too sound-absorbent so that it feels like "speaking into a bag".
- Ordinary low sounds such as whispering or chairs scraping should not be amplified.

Quality labelling of housing, schools and preschools
The Government of Sweden asked the National Board of Housing, Building and Planning to analyse existing quality labels related to the indoor aspects of buildings and to develop a system for quality labelling of housing, schools and preschools (8). Schools and preschools are considered in the broad sense, and the report of the National Board of Housing, Building and Planning therefore proposes that the labelling covers settings for children aged 1–19 years.

Because the function of different rooms in a school varies greatly, a proposed quality label for a school has four aspects:

- Common aspects for all school buildings
- Specific properties of buildings
- Specific properties of rooms
- General comments on the management of schools.

A quality label for schools should relate to accessibility for people with various types of functional disadvantages, such as people in wheelchairs and people with impaired vision or hearing.

Good thermal climate is imperative for concentrating at school, and the acoustic environment must also be adapted to educational situations. The report of the National Board of Housing, Building and Planning mentions the regulations that already exist for school environments.

Nina Wahlberg from the Municipality of Hanninge is one of the environment and quality coordinators who are going to test the proposed quality label for 20 schools and preschools (9). Wahlberg says that the Municipality already has information about the buildings but not on such factors as accessibility or noise around the school. The quality labelling provides an opportunity for comparing schools, which may be of interest to parents when they choose school or day care for their children, says Wahlberg.

Environmental health quality labelling for schools
In 1998 the Government of Sweden prepared legislation on environmental health quality labelling for schools (10), with criteria for general management, occupational health, health promotion and the physical environment. To receive this quality label, a school must function so that all students and staff obtain insight into the importance of good occupational environments and health and well-being.

The government prepared a bill on Sweden's environmental objectives and targets and presented it in spring 2001 (11). The section relevant to schools is called good built environments, which contains seven interim targets, the third being (12): "By 2010 the number of people who are exposed to traffic noise in excess of the target values approved by Parliament for noise in dwellings will have been reduced by 5% compared with 1998."

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Annex 8. Primary schools in the Netherlands

by Marie Louise Bistrup

Children start elementary school at age 4–5 years (preschool class).

According to a new law, from August 2002 all children are required to attend school when they turn 4 years. The elementary school is always located in the community, and the average mainstream primary school (excluding the 3% of children in special education) in the school year 1999/2000 had 218 pupils.

Schools tend to be clustered in complexes between schools of different religious denominations (such as Roman Catholic, Protestant and Islamic) or schools with a special educational method (such as Montessori, Dalton or Jenaplan) but also with such facilities as day-care centres, before- and after-school centres, social welfare facilities, adult education and a library. These are called "broad schools". In 2010, 10% of the schools for primary education are expected to be part of a broad school.

After 8 years at the elementary school, children go to the secondary school. These are often clustered into complexes, with several types of schools in one building serving large catchment areas.

Building boom
The Netherlands currently needs larger and more differentiated types of schools, leading to considerable school-building activity. The number of subjects at secondary schools has increased, and new schools are therefore built to satisfy students' demands for making these choices. Specialised schools require a catchment area of 1000–1500 students, and in larger cities two or three existing, older schools often collaborate on building a new large school (interview, J.J.M. Cauberg).

Legislation and guidelines
The Noise Abatement Act is the main law governing environmental noise. The Noise Abatement Act stipulates limit values for all types of noise in sensitive areas: schools, hospitals, residential areas and other health care facilities. The Act specifies guidelines on how much environmental noise the façade of schools has to attenuate. There are no separate laws on noise for schools and day-care centres.

General measures of administration (similar to a statutory order) are issued pursuant to laws. The Environmental Management Act (1) has several general measures. The one from 1998 (2) on private houses and commonly used buildings deals partly with regulations for schools.

The building regulations comprise a series of separate orders on different aspects of buildings under the Housing Act and other laws. For example, one order including the different regulations on building standards, including acoustics, was renewed in 1993. The present building regulations (3) only regulate residential buildings and the like. However, the revised building regulations coming into effect on 1 April 2002 (4) regulate environmental noise and reverberation time for buildings used for educational purposes.

The various laws and regulations deal with several aspects of noise:

- Noise propagating from buildings into the environment;
- Insulating a building against environmental noise;
- Noise propagating between buildings and noise propagating between different rooms in a building;
- Noise from equipment; and
- The acoustics within a room.

The Environmental Management Act (1) regulates the maximum equivalent environmental noise outside schools for different parts of the day:

- 50 dB(A) between 0700 and 1900;
- 45 dB(A) between 1900 and 2300; and
- 40 dB(A) between 2300 and 0700.

For schools built under the older regime of regulations, 5 dB(A) is added to these levels. The maximum equivalent levels for background environmental noise within the building for different parts of the day are:

- 35 dB(A) between 0700 and 1900;
- 30 dB(A) between 1900 and 2300;
- 25 dB(A) between 2300 and 0700.

The building regulations govern noise in school buildings between rooms with different functions in primary schools (5) and secondary schools and special education schools (6). These regulations specify noise-insulation criteria for different functional rooms, such as exercise rooms, playing rooms or teaching rooms, both for primary schools and special education schools.

The general guidelines of the Noise Abatement Act govern noise from equipment. Schools and their equipment have no specific rules.

The new edition of the building regulations states that the average reverberation time should not exceed 1.0 seconds in a classroom and 1.5 seconds in exercise rooms.

The Government Buildings Agency (Ministry of Housing, Spatial Planning and the Environment) issued guidelines in September 1999 (7) covering the characteristics and reverberation time for different kinds of rooms in educational settings. The recommended reverberation time in ordinary classrooms is 0.6–0.8 seconds.

Other regulations address the maximum background noise indoors. The maximum background indoor noise level is 30 dB(A) for classrooms used for academic purposes and 35 dB(A) for rooms with other functions such as practical rooms.

Acoustics in day-care centres
There are guidelines without legal status on acoustics for day-care centres (8). For the living-rooms of day-care centres the average reverberation time should not exceed 0.7 seconds (0.9 seconds when the room is empty). The airborne sound insulation index between the quiet rooms (bedrooms and office) and the other rooms has to be equal to 0 dB and at least –10 dB between the different living areas.

Some current conflicts are important for schools. The building regulations specify criteria for building construction, but schools are not included. The Noise Abatement Act limits indoor noise in schools to 30 dB(A), whereas the building regulations stipulate 35 dB(A) for buildings in general (interview, Peter Bijvoet).

A general measure under the Environmental Management Act (1) prohibits new schools from being located along roads with heavy motor-vehicle traffic, because schools are considered more sensitive to noise than industry. Nevertheless, some schools have been built near busy roads despite an internal sound level from environmental noise exceeding 35 dB(A).

Ventilation
The schools have been traditionally ventilated naturally, and the most recent schools are naturally ventilated for financial reasons. But new schools close to noisy roads often have mechanical ventilation. The new schools must follow the building regulations, and most new schools seem to have established good acoustics.

Municipalities
The municipalities enforce the building regulations. Many parties are involved in determining the standards for a new school. The developer, the school board, the municipality and sometimes an acoustics expert are involved. Acoustic consultants and engineers help customers to find good solutions that comply with legislation and guidelines. If the recommended solutions have the same effects as the guidelines but otherwise differ from the prescribed methods, the municipality can decide whether the recommended solution can be used.

Building guidelines are described as objectives; this provides opportunities for experimenting with alternative solutions to reduce noise inside and outside schools and day-care centres (interview, Peter Bijvoet).

Reducing noise in primary schools
The total budget for building a school in the Netherlands is limited. This means that choices have to be made and priorities set. Unfortunately, good acoustics is not high on the list of priorities in building schools. Improving poor acoustics is not a priority either. A carpet is usually not adequate to compensate for the lack of an acoustic ceiling. Carpets do not have the same acoustic properties, and the municipal health services recommend prohibiting carpets in schools because it creates problems for allergic children.

A simple solution is that schools may install pin boards or place panels against the wall to absorb some noise.

Reverberation time and student behaviour

In 1998 (9), reverberation time and student behaviour were compared in two classrooms at the primary school De 4 Heemskinderen in Etten-Leur, the Netherlands (Consultants Peutz & Associes B.V.). One had acoustic tiles and the other did not.

The reverberation time was 0.41 seconds in the classroom with a class A acoustic ceiling and 0.96 seconds in the other room. The floor area of each classroom was 55 m^2, and the effective absorption coefficient of the acoustic ceiling was 0.73. Absorption coefficients are higher in laboratory situations because of the diffused sound field in the reverberation chamber.

The reverberation time was measured with and without children in the treated and the untreated room. Each pupil in the untreated room added 0.22 m^2 of absorption.

In the treated room, the reverberation times were very similar between the empty and occupied states.

Speech intelligibility was measured as the percentage articulation loss of consonants (%ALcons).

According to the report (9), the %ALcons in an empty treated room was 3.2% (regarded as good) and 7.6% in an empty untreated room (regarded as fair).

During lessons, the average noise level in the room with acoustic tiles was 8–9 dB(A) lower than that in the other room, and the respective peak levels were 63 and 72 dB(A). While the noise was being measured, activities and the cause of about 30 peak sounds, such as shifting chairs, shouting and the teacher quieting the children, were observed and noted in the noise report (9).

The children's behaviour was observed in the two classrooms, and orderly and disorderly situations were noted. Disorder could follow a situation in which the teachers gives a lesson and then leaves the room, with children studying independently. The noise levels rose from 44 dB(A) to 68 dB(A) and then declined to 50 dB(A) when the teacher re-entered. The teacher in the room with acoustic tiles found restoring order easier than did the teacher in the room without acoustic tiles.

The acoustics of the classrooms

The reflective qualities of different surfaces are important.

Reverberation time is significantly lower in the treated rooms.

Impulse response measurement without children present in the classroom measures the response in the room of the impulse, and all acoustic parameters can be derived from this.

Speech intelligibility, measured as percentage articulation loss of consonants, was 3% in the treated classroom, which is considered good, and 8% in the classroom without acoustic tiles, which is considered fair.

Sources: interviews, M.P.M. Luykx, Peter Bijvoet and J.J.M. Cauberg

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Annex 9. Determining noise exposure at discothèques in Reggio Emilia, Italy

Summary by Nicola Prodi

Aims

The project, which was carried out in 1994–1995, aimed at:

- Increasing knowledge about and determining the noise exposure of both workers and patrons at discothèques;
- Determining the environmental noise levels outside discothèques;
- Gathering data useful for protective interventions; and
- Developing models of health communication that can be used to increase the awareness of the hazards associated with noise.

Methods

Detailed acoustic measurement was carried out at seven discothèques in the town of Reggio Emilia, Italy, including:

- Continuously monitoring the environmental sound level outside;
- Continuously monitoring the sound level at the centre of the dance floor;
- Monitoring the sound level at other places in which patrons were located; and
- Monitoring the sound level at workplaces for a fixed time interval.

The hearing ability of workers was tested, and audiometric tests were performed on patrons before entering the discothèque and immediately afterwards. The tests assessed response times to light and sound stimuli among 106 patrons before exposure to noise in the discothèque and afterwards (212 tests). Finally, 7466 questionnaires were distributed to typical patrons and collected at the entrance of discothèques.

Results

Environmental impact

Based on the data measured, the sound level of the music at the centre of dance floor weakly influences the level of external environmental noise. Nevertheless, the peculiar frequency characteristics tend to make the noise very detectable for nearby residents. In any case, the noise level close to the discothèques always exceeds the limits prescribed for the respective area. The main reason seems to be the substantial motor vehicle circulation specifically related to the discothèques, the grouping and transit of people and ordinary traffic.

Noise exposure of workers

Thirty-six percent of the workers had a daily personal exposure ($L_{ep,day}$) of 85–90 dB(A) and 28% exceeding 90 dB(A). The risk from exposure to noise was high, and current law mandates measures to reduce the risk. Although the technical means of solving the problem are simple (reducing amplification), both commercial and competition considerations comprise a barrier. Continuous monitoring is suggested.

Noise exposure of patrons

The noise exposure of patrons was determined using the same methods as above. The average $L_{ep,day}$ for a typical patron was 99.3 dB(A). Assuming one weekly session at the discothèque, this becomes an $L_{ep,week}$ of 89 dB(A). This exposure is much higher than that of a worker in a very noisy factory working 40 hours per week.

Health aspects

The audiometric tests investigated the hearing ability of 92 workers. The study found a diffuse (37%) alteration in hearing ability. A minimum audible level above 25 dB(A) was found in the frequencies typical of noise damage. Moreover, other effects of noise have been reported, such as tinnitus, and relevant extra-auditory effects were found.

The comparative audiometric tests on the patrons before and after attending the discothèque found an impressive rise in the threshold for listening, whereas the responses to visual stimuli still seemed acceptable.

The extensive questionnaire survey of patrons allowed specific preferences and habits to be determined according to sex, age, level of education and other parameters. Interestingly, younger people prefer higher sound levels, and a noteworthy proportion of the respondents drink alcohol at the discothèque even if they do not usually. Moreover, the great majority of interviewed people drive a car from the discothèque even if they consumed alcohol.

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Annex 10. The childrens book: Good you've got ears, good you can hear!

[cover]

Good you've got ears,

good that you can hear!

(English edition of text in the German picture book: Gut, dass du Ohren hast, gut, dass du hörst!)

The Independent Institute for Environmental Concerns welcomes requests for permission to translate this book. The text has been translated into English because the project hopes that there will be interest in publishing this in English and other languages. If a government or nongovernmental organisation is interested in translating the book for the purpose of publishing the book in another language, the Independent Institute for Environmental Concerns can arrange for the use of the illustrations. In addition, the section on further reading could be adapted to include material published in the language of the translation. Applications and enquiries should be addressed to:

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[title page]

Good you've got ears! Good that you can hear!

A picture book for children and parents

Author	Susanne Neyen
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Publisher	Independent Institute for Environmental Concerns

Dear parents and educators,

This picture book for children and adults takes into account their differing ways of perceiving the world and acquiring knowledge. Throughout the book, the left page is designed for the child and the right page for the adult, so that they can sit side by side, each viewing his or her "own" page. Children will be captivated by the lively illustrations and motivated by the easy-to-learn rhymes to think about hearing-related habits and behaviour. The additional information, graphics and illustrations found opposite the child's page will help adults in explaining the topic at hand clearly and vividly.

In turning the pages, reading aloud and looking at the pictures together, children and their adult companions will gain awareness of the kinds of behaviour that can damage their own or their friends' hearing. While the book instructs parents and educators on such potential hazards, children playfully learn about their ears, acquiring understanding of how wonderfully they work and how important it is to take care of them. Our aim is to foster in children an enduring appreciation of good hearing as well as their confidence in protecting their health.

At the same time, we want to help bridge the gap between hearing-impaired people and society at large. Children (and adults) with impaired hearing often have difficulty communicating. However, this should not justify standing on the sidelines. What good are our ears when we no longer listen to one another, preferring television or headphones to conversation? Human relationships demand intensive listening, an acquired ability that children must practice. Many adults will find it useful to practice this commonly neglected skill right along with their children.

The book can be read from cover to cover, or particular pages or topics may be selected and focused on. The back of the book has suggestions for entertaining listening games that demonstrate the importance of a good sense of hearing.

What the rabbit uses his ears for

This is Rocko the rabbit.

Shhh!... Rocko's still asleep.

Look, there's somebody else back there!

It's the sly fox – he's sneaking up on Rocko.

He wants to catch him.

Run away, Rocko, run!

But Rocko doesn't see the fox.

How can he? He's sound asleep.

But look now – Rocko is pricking up his long ears.

He can hear something rustling in the grass.

His ears stand guard, even when Rocko's sleeping.

Rocko wakes up and runs away... Saved from the sly fox!

Good Rocko's got those fine long ears –

he always knows when the sly fox is near!

Humans have five senses: sight, hearing, smell, taste and touch. When asked to name the most important sense, most people spontaneously answer sight. Hearing is thought to be somewhat less important. However, our ears allow us 360-degree surveillance of our surroundings, whereas the range of our eyesight is limited to the direction we are facing. Only our ears can monitor what goes on behind our back.

Make clear to your children how much we rely on good hearing to communicate. Without hearing we could hardly learn to speak a language. It also serves to warn us when somebody on the street calls out “stop!” or “look out!” or when drivers honk their horn.

With your children, consider all the things our ears can do. They can...

Hear in the dark...

Hear around a corner...

Tell us the direction from which a sound is coming and let us orient ourselves...

Recognise somebody by their voice and tell whether the voice is friendly, angry, excited or afraid...

What Paul uses his ears for

Paul’s sleeping, too. Paul doesn’t have to worry about the fox. Paul is safe in bed.

But then a mosquito comes in through the window. It hums very softly, but Paul still hears it. He wakes up and ... shoos it away.

“Stupid mosquito!” thinks Paul, “Good that I woke up before it bit me!”

Paul’s already got 13 mosquito bites, and that’s enough!

Even when I’m sound asleep,

my ears hear every little peep.

In my dreams there's something quietly ringing

and the birds in the tree by my window are singing.
"Time to get up, out of bed!" Dad is saying.
On the radio soft music is playing.
Over the track train wheels are crashing.
Water runs cool in the sink, brightly splashing.
Coffee gurgles into the pot that Mum's making...
All the things that I hear when I'm waking...
Good you've got ears, good that you can hear.
Good you've got ears, good that you can hear.

Song by Gerhard Schöne

Just look at the ears!

Paul shows us his ear, which saved him from the mosquito.
From the outside, his ear looks like a big seashell.
It catches all the sounds around...
...just like Rocko the rabbit's ears.
But Rocko's ears are even bigger –
and he can move them!
Harry the hippo closes his ears when he dives.
That way, no water can get in.

My two ears hear all around –

they can pick up any sound.

This is how I hear!

The visible *outer ear* leads sounds into a narrow tube, called the *auditory canal*, which carries them to the parts of the ear hidden within the head.

The *eardrum* vibrates when it is hit by sound waves.

Three tiny bones – named, for their appearance, the *hammer*, the *anvil* and the *stirrup* – transfer the sound vibrations from the eardrum to a fluid that fills the *cochlea*, the snail-shaped canal in the inner ear. In humans the cochlea has two and a half coils.

The vibrations spread through the fluid as waves, which in turn cause extremely tiny, fine *hairs* in the cochlea to sway.

These hairs then send nerve impulses via the *auditory nerve* to the auditory centre in the *brain*.

Caution: Do not clean the ears with cotton swabs. This can result in injury to the eardrum and clogging of the auditory canal with earwax.

What things are loud? What things are quiet?

A rule of thumb

Prolonged exposure to noise levels of more than 85 dB(A) can cause damage to your hearing.

If the noise level causes pain, hearing damage is imminent. Pain has a warning function for the body. If we touch a hot burner on the stove top, for example, the pain makes us pull our hand away immediately, thus preventing further harm. The body reacts similarly to being cut by a knife blade or to blinding light, such as sunlight.

Our reaction to painfully high noise levels should be the same: cover the ears and run away, or – better yet – switch off the source of noise!

The decibel (dB)

The decibel (dB) is the unit used to measure the pressure of sound waves. The decibel is a logarithmic value, and numbers therefore convey little about the actual volume of sound. An increase of 10 dB corresponds to a doubling of the perceived volume but to a tenfold increase in sound energy. This means that when a sound becomes 10 dB louder, it produces the same effect in one tenth of the time. Accordingly, exposure to a noise level of 85 dB for a period of 40 hours represents the same stress on the ear as a level of 95 dB over 4 hours or 105 dB over 24 minutes.

A single firecracker can be enough to damage the ears for life.

Over time, listening to loud music on headphones also causes hearing loss.

Noise level in decibels (dB(A))

Toy pistol held directly to ear	180
Rifle shot near muzzle	160
Whistle or rubber duck held directly to ear	140
Rock concert	120
Loud discotheque	
Maximum volume on portable music player	
Circular saw, pneumatic hammer	
Lorry driving 5 metres away	100
Main street	80
Conversation	60
radio at low volume	
Quiet room during day	40
Whispering	
Soft rustling of leaves	20
Quiet room at night	
Silence	0

Damage possible from single exposure	140
Pain threshold	120
Onset of risk to hearing with long-term exposure	85
Upper limit for focused mental work	40
Relaxation, quiet, sleep	20
Hearing threshold	0

How hearing can be damaged

All sounds cause waves in the fluid in the cochlea. The height or strength of these waves depends on the volume of the sound, just as the height of waves on the sea depends on the strength of the wind. The tiny hairs in the inner ear are elastic and sway with the impact of each wave, much like reeds standing in the water sway with each wave movement. Very loud sounds, especially prolonged ones, can damage the fine hair cells in the inner ear. Here's an example that illustrates this:

Hearing a quiet sound is comparable to a calm sea. The waves are low and the reeds sway gently.

When the sounds become louder, it is as if the wind is increasing. The reeds sway harder.

Very high volumes are like a storm in the ear. The delicate hairs in the inner ear can break off, resulting in hearing loss. Unfortunately, once the little hairs are broken, they can't grow back. This means the damage to your hearing is permanent.

Today Grandpa and Grandma have come to see us.

Grandpa is reading me my favourite fairy tale, “Little Red Riding Hood”.

Little Red Riding Hood asks,

“Grandmother, why do you have such big ears?”

“All the better to hear you with!”

answers the wolf.

My Grandpa doesn’t need big ears to hear me better.

He has a new hearing aid.

Now he understands everything I tell him.

With hearing aid or without,

Peter knows what I’m about.

Just like my friend Peter – he has a hearing aid too. He’s always had one. We understand each other just fine.

Recognising hearing impairment in children

The earlier an existing hearing impairment in a child is recognised, the better. The hearing problems of some children go undiscovered until they are well into school age. These children often have social, emotional and school problems that could have been avoided through early treatment and/or providing hearing aids. Any of the following may be a sign of hearing impairment in a child:

- The child always turns a certain ear (the one that functions better) toward the source of a sound.
- The child seems unsure and has to ask for information more often than normal.
- When speaking and especially when listening, the child seeks visual contact, trying to “read” the speaker’s lips.
- The child speaks more loudly than normal.
- The child’s active vocabulary is underdeveloped.
- The child has difficulty locating the source of a sound or listening to a person moving in the room.
- The child cannot distinguish signals and voices from background noise and does not react to loud noises or when spoken to.
- The child confuses similar sounds when speaking and also in writing dictation (such as *tap* and *cap* or *beg* and *bed*).
- Sounds or words are missing in dictation.
- The child has difficulty keeping up in oral arithmetic exercises.

- The child cannot continue simple rhyming patterns.
- The child cannot fully follow and execute directions and tasks with several parts.
- Listening and action are only possible sequentially and not simultaneously.
- The child has difficulty clapping, moving and speaking simultaneously when learning poems and songs, and also in separating words through clapping.

Which sounds are high-pitched?

Which are low-pitched?

Bright and high is the voice of the lark

when she sings her song to me in the park.

When the bear growls low from the mountainside,

you can hear him from far and wide.

Tip: Young children often have difficulty recognising from the pictures whether a sound is high or low in frequency. Demonstrate the sounds and make them together with the children – all growling low like a bear and squeaking high like the mice.

How we perceive different tones

The most advanced electronics cannot even approximate the ability of healthy hearing. The human ear can perceive sound waves over a frequency range of 20 to 20,000 hertz (Hz). The higher the frequency – that is, the number of wave cycles per second – the higher the pitch. Leaving out the complicated details, we will focus here on the principle behind people's ability to hear different tones.

During the act of hearing, the sound waves in the cochlea spread out, setting the fine sensory cells in vibration. However, they never stimulate all of them, but only certain ones. These waves can be thought of, again, as waves at sea that gently peter out when they reach the beach. As they "break" they form a tiny vortex, or whirlpool. At any given moment, the sensory cells precisely at the point of the vortex are those most strongly stimulated. The sensory cells at the entrance to the snail-like cochlea perceive high tones. Low tones are perceived by the sensory cells near the tip of the cochlea's spiral. Thus, the different frequencies (pitches) are assigned to different sections of the cochlea, as on a piano keyboard.

Let's do a mental experiment. We "unroll" the spiralled cochlea, stretch it out and stand it on end. Think of it now as a 20-story building. A red carpet runs from the lobby up the stairs the residents climb to reach their apartments. Where will the carpet wear out the soonest? Right! On the lowest floors, through which all of the building's residents have to pass. Very few will go all the way up to the 20th floor – certainly nobody who doesn't have to. The sensory cells are similar. Those located near the entrance to the cochlea (for high pitches) experience more wear and tear than those closer to the tip (for lower pitches). This "stair-climber effect" occurs above all in hearing loss associated with ageing, in which we tend to lose hearing sensitivity especially in the high-frequency range.

This is my big brother, Walter. He likes to listen to music. When he comes home, he goes straight to the stereo, puts on his headphones and turns the volume way up – much too loud! I'm always telling him it's bad for his ears.

I also keep telling him he shouldn't stand right in front of the speakers when he goes to concerts. Too bad his ears don't shut themselves when it gets too loud, like Harry the hippo when he dives.

Put some earplugs in your ears,

or you'll be deaf in a couple of years!

A few tips for big brothers and sisters

At the disco or a concert

Look for discos that aren’t too loud.

Don’t stand right in front of the speakers.

Take breaks every so often in a quieter place.

Use hearing protectors: earplugs (available in pharmacies and home supply stores).

Tips for listening to a portable music player

Get a portable music player with an automatic volume limiter.

Don’t listen to a portable music player in loud places. (You’ll automatically turn the volume up louder than usual.)

Don’t listen to headphones for hours at a time.

Walter went to a rock concert last night. He’d been looking forward to it for days. He wouldn’t talk about anything else.

Now he can’t hear very well and his ears are ringing.

Walter’s favourite band came to play –

but something went wrong yesterday.

Numbness, sudden hearing loss and tinnitus

A feeling of numbness (temporary rise in the hearing threshold – you hear everything as if through cotton) or a whistling, rustling, buzzing or ringing in the ears (tinnitus) are warning signals. Usually the ears recover within a few hours or by the following morning. Still, these strong "statements" by your ears must be taken seriously. Repeated occurrence of any of these can eventually result in permanent hearing damage.

Take note:

Sudden hearing loss: Usually acute and affects only one ear. Medical attention should be sought immediately.

Tinnitus: If the sounds in your ear(s) continue for over 2 days, the attention of a specialist is urgently advised. Within the first 2 weeks, your chances of healing are very good. After that they decrease rapidly.

For comparison

Temporary numbness or tinnitus as a reaction of the ear to noise can be compared with a sunburn. Just as the skin recovers gradually following a sunburn, so too do the hearing cells (as long as they haven't suffered acute damage above the pain threshold and broken off).

However, repeating such conditions can lead to long-term consequences. Skin will age faster, develop wrinkles and spots, and in the worst case, cancer. The ears are similar. The ageing of the hearing cells will accelerate and, in the worst case, exposure to noise will cause permanent hearing loss.

Ears need protection just as much as our skin does!

Headache, anger, tiredness...

quiet will help against the stress.

Mum's coming home – I can tell it's her by her footsteps. Mum walks quickly and lightly. Dad's footsteps are heavy, and my big brother Walter is always in a hurry and runs up the stairs three steps at a time.

Mum works in a big office. Sometimes she's tired and has a headache when she gets home. If I'm quiet for a little while, she feels better soon and then we can play together.

Noise gets under your skin

Science cannot define precisely when sound becomes noise. How disturbing a given pitch or volume is depends on the individual. What is certain, however, is that noise is a stress factor – it negatively affects how we feel.

All effects of noise on the body other than on the ear itself are called extra-auditory (or extra-aural) effects. Noise "gets under your skin". At the heart of this colloquial saying lies a scientific truth.

The human organism reacts to noise with numerous stress-specific symptoms, including general nervousness, aggressiveness, accelerated heart rate and increased blood pressure. If such symptoms are allowed to persist over a period of years, they can lead to high blood pressure and circulatory disorders.

The influence of noise on sleep is of special importance. Even if noise does not keep us awake at night, it has negative health effects. The body cannot grow accustomed to noise. Although we may no longer consciously register it after a while, it continues to affect us physiologically.

Treat yourself to absolute quiet as often as you can. See to it that you and your children sleep in the quietest rooms in your home. Keep all noise sources away from the bedrooms. Turn off the radio and television at night.

Hey, look what I can do! I can add numbers, write my name and do really tricky puzzles.

I can do things like that best when it's really quiet. Then I can think better!

Quiet gives me the power to think –

I'll have this puzzle done in a wink!

Concentration, noise and school work

Noise is increasingly likely to reduce performance as the difficulty or complexity of tasks and the period of exposure increase.

Many children like to listen to music while doing their homework. Try to get your children to agree that tasks requiring logical reasoning, creative thinking and memorisation are to be done in quiet surroundings. Drawing, painting or crafts, on the other hand, can be done with music playing in the background.

Studies have demonstrated the following effects of noise on children's performance:

- Decreased ability to concentrate;
- Reduced reading performance;
- Reduced accuracy in recognising errors;
- Decreased persistence in solving difficult problems (earlier resignation and lower frustration threshold); and
- Dependence on simplistic problem-solving strategies and rigidly applying them.

Make sure that your children can study and do their homework in quiet surroundings.

It's evening and Dad has come home from work. We're having supper together. This is my favourite part of the day. We can all tell each other what we've done.

When we've eaten and I've washed up, I get to listen to a bedtime story.

When someone's talking I listen up –

if you want to understand, then don't interrupt!

Being able to listen...

...takes practice. Children, regardless of their age, have problems, worries and joys that they want to express. Sometimes you can tell only by their tone of voice, not their words, that something is wrong.

Take some quiet time every day to listen. Enjoy calm moments with your children consciously. These are all too rare in our noisy environment.

Many people have lost the ability to enjoy, or even tolerate, quiet. Instead, they prefer to have the sound of the radio or television constantly in the background.

Being heartily loud and relaxing quietly are not mutually exclusive. Rather, it's important to have alternating phases of both.

"It is received common wisdom to consider one of our senses more important than another. For over two thousand years occidental culture has placed seeing above hearing. Now we are 'discovering' the ear. The point is not to invert the accepted hierarchy of the senses, however, but to do away with it completely.

The message is that none of our 'instruments' is less significant than another. And no injury to or loss of any one of our sensory organs is less serious than an injury to another." (Karl Karst – Schule des Hörens (School of Hearing))

The following section has ideas for group games in which the ears play the leading role.

Some can be played spontaneously, without further preparation, whereas others require at least minimal introduction and/or planning.

Prick up your ears! We wish you lots of fun *listening to*, *hearing* and – not to forget! – *understanding* each other.

We'll be hearing from one another...

Susanne Neyen

Listening and hearing games

Telephone

The children sit in a circle. The first child makes up a short sentence and whispers it in the ear of the child sitting next to him or her. The second child whispers the sentence he or she has heard to the next child. This is continued around the circle until the sentence returns to the first child, who compares what he or she hears with the original sentence.

Despite the careful listening required, this game generates a lot of laughter because of the changes the original sentence often goes through.

The game could foster empathy with hearing-impaired people, for whom listening to others presents special challenges.

Blind man's buff

This game is best played outdoors where there is lots of space.

One child ("the blind man") is blindfolded. He or she has to guard "treasures", such as scarves or coloured strips of paper, which are fastened to his or her clothes. The other children try to grab as many "treasures" as they can but must not allow themselves to be caught. When a child is caught by the "blind man" he or she has to take over the role.

The winner is the child who gathers the most "treasures" without getting caught.

In this game, children gain skill in orienting themselves spatially by the sounds they hear. They learn to locate the source of a sound by its direction.

Guessing sounds and actions

The children are separated visually from the person making the sounds.

Based on their sounds alone, they have to try to recognise everyday objects, such as a vacuum cleaner, telephone, bell or ticking clock; various materials, such as wood, metal or glass; or familiar activities, for example hammering, splashing in water, playing with a ball, brushing teeth, or stirring pots.

Inventing sounds

The children form two or more teams. The teams are separated from one another visually by a curtain or other screening object. The children invent as many different sounds as they can using only their own body. (Normal speaking or singing sounds are not allowed!)

The team that invents the most sounds and best guesses the sounds made by their opponents wins.

I hear something that you can't hear...!

This is a variation on the well-known game I spy with my little eye...

Here, though, it is good ears and not eyes that are needed. On a walk, stop and stand still at a random point in the forest, meadow, etc. Close your eyes and listen. The children describe all the sounds they hear, including, if possible, the directions from which they come.

The children will become conscious of how many different sounds to which they normally do not pay attention surround them in their everyday lives.

Sound concentration

This game helps children develop concentration and acoustic differentiation.

First, make a sound concentration game together with the children. It consists of 18 (or more) matching opaque containers (such as matchboxes or black film cylinders) partly filled with various materials or objects (such as peas, sand, nails, small bells or marbles, seeds) that produce sounds inside the containers. Each material is placed in two containers, so that each noise-maker has a matching counterpart.

The pieces – here the noise-makers – are laid out as in a customary memory game.

Then the search begins for the matching pairs.

The noise-makers are shaken to produce "their" sound.

The level of difficulty can be varied by allowing only one or multiple shakes.

Squeak, little mouse or Knock, knock – who's there?

The children sit in a circle. One player is blindfolded. This child moves around inside the circle and sits down on another player's lap. The blindfolded child calls out "Squeak, little mouse!" The player on whose lap the blindfolded child is sitting on answers with a mouse-squeak. If the blindfolded player guesses correctly who the "little mouse" is, the "little mouse" then takes the role of the guessing player.

In a variation on this game, one child is blindfolded and the other players knock lightly on his back in turns, saying, "Knock, knock – who's there?" If the blindfolded child guesses correctly who is knocking, the latter takes the blindfold and becomes the next player to guess. One advantage of this version is that the teacher can more easily participate. Another is that the players identify each other by hearing alone, whereas in Squeak they can rely partly on touch.

Have fun playing!

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We wish to thank Gerhard Schöne for his kind permission to reprint the second verse of his song "Augen, Ohren und Herz" (*Eyes, ears and heart*). All three verses of this wonderful song can be heard on the CD *Jule wäscht sich nie – Gerhard Schöne – die besten und ganz neue Lieder* (1997) (Jule never washes – Gerhard Schöne – the best songs and new songs) and are fun to sing along with.

This book could not have been produced without financial support from the European Commission. Our heartfelt thanks go to Marie Louise Bistrup and Lis Keiding, National Institute of Public Health, Copenhagen, Denmark, whose dedication made the book possible. From the original concept to printing, they stood by this book with great commitment, contributing many constructive ideas to its realisation.

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And, in closing, a joke:

Little Jack runs to his mother crying,

"Our downstairs neighbour's a liar!"

"Why?" his mother asks.

"He told me to cut open my drum and there would be a big surprise inside!"

Further reading

Books for kindergarten and nursery school children

Hanna Johansen and Jacky Gleich, *Sei doch mal still*, Carl Hanser Verlag, Munich, 2001

Books for primary school children

Was ist was? Band 50: *Unser Körper* and Band 80: *Tiere – wie sie sehen, hören und fühlen*, Tessloff Verlag, Nuremberg

Books for secondary school students and adults

Gerald Fleischer: Lärm der tägliche Terror, *Trias Verlag, Stuttgart, 1990*

Gerald Fleischer: Gut Hören – Heute und Morgen, *Median-Verlag, Heidelberg, 2000*

Immo Kadner: Akustik in der Schulphysik, *Praxis – Schriftenreihe – Abteilung Physik – Band 51, Aulis Verlag Deubner & Co KG, Cologne, 1994*

Brochures and pamphlets

Gesundheitsschutz 5: Gehörschäden durch Musik, *Bundesanstalt für Arbeitsschutz,1995, tel.: +49 0231/9071-0; fax: +49 0231/9071-454*

Lärm macht krank, Independent Institute for Environmental Concerns, 1995, tel.: +49 030/ 428 49 93-4, fax: +49 030/428 00 485

Projects and materials

Teaching materials

Landsberg-Becher, J.-W. u.a., Lärm und Gesundheit*, Materialien für 5.-10. Klasse [10–16 years old], Federal Centre for Health Education, Cologne, 1997*

Landsberg-Becher, J.-W. u.a., Lärm und Gesundheit*, Materialien für die Grundschule [6–10 years old], Federal Centre for Health Education, Cologne, 2001, tel.: +49 0221/8992-0; fax: +49 0221/8992-300; Web: www.bzga.de*

Projects and contacts

Take care of your ears

This project was conceived for primary and lower secondary school children and is currently running in various cities in Germany.

It comprises various lesson units and is carried out by ear specialists and hearing aid technicians. Contact: tel. +49 064 21/ 293-0.

Laut ist out

The Independent Institute for Environmental Concerns conducts projects on the subject of hearing for age groups 5 to 19. Contact: Susanne Neyen, Tel. +49 030/ 428 49 93-4.

Susanne Neyen, concept and text

Susanne Neyen (born 1965), two children, Dipl. Ingenieur. For the last 7 years, active in research on the effects of noise. Experience with schoolchildren of various age groups in numerous projects. Studies on the subject of hearing loss through leisure noise.

Martina Genest, illustrations

Martina Genest (born 1964) lives with her husband and daughter in Berlin. Teacher at a school for developmentally disabled children. Studies included cartooning and drawing from the human figure under the renowned F.W. Bernstein at the Universität der Künste Berlin (Berlin University of the Arts). For years has illustrated brochures and neighbourhood newspapers. Work on this picture book has whetted her appetite for more!

Independent Institute for Environmental Concerns, publisher

The Independent Institute for Environmental Concerns was founded in 1990 in the tradition of the citizens' movement of the German Democratic Republic. It is an academic and research institute as well as a citizens' organisation. It strengthens the public involvement of citizens through education and consultation in environmental policy. The institute publishes brochures, pamphlets and handbooks and conducts seminars, workshops and conferences.

For further information, see www.ufu.de.

[Back cover]

Good you've got ears! Good that you can hear!

This book is about hearing. It makes clear just how valuable and yet delicate this sense of ours is – and thus how important it is to take good care of it. A picture book made for children and adults, it takes into account their differing ways of perceiving the world and acquiring knowledge. In turning the pages, reading aloud and looking at the pictures together, you and your children will marvel at how the ears work and all that they enable us to do. At the same time, the book will motivate you to reconsider the kinds of behaviour that can damage people's hearing or that of others. The book finishes with a section on entertaining games in which the ears play the leading role.

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