

Noise in the preschool

Health and preventive measures

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To my family

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Abstract

This thesis is based on noise recordings and health evaluations carried out at preschools in the northern part of Sweden. Sound level recordings were made on individuals and by use of stationary devices in dining rooms and play halls. Health evaluations were based on ratings by use of questionnaires and by analyses of cortisol.

The average equivalent individual noise exposure was 71 dB(A). The average equivalent noise levels in the dining room and playing halls were 64 dB(A). The hearing loss of the employees was significantly higher for the frequencies tested than in an unexposed control group. Symptoms of tinnitus were reported among 31% of the employees. Noise annoyance was rated as somewhat to very annoying, and the voices of the children were the most annoying noise source. The dB(A) level and fluctuations of the noise exposure were significantly correlated with the number of children per department. Stress and energy output were pronounced among the employees. About 30% of the staff experienced strong burnout syndromes. Mental recovery was low as indicated by noise fatigue and high levels of stress after work. Increased cortisol levels during work were associated with higher number of children present at the department.

An essential finding of the thesis was that noise and noise sources may impair the pedagogic work, thereby increasing the work load of employees. It is concluded that noise exposure in the preschool, isolated or in combination with other stressors, plays a fundamental role in the building up of acute as well as long term stress. An intervention study implementing six acoustical and seven organizational measures was tested, aimed to improve the noise situation in the departments. Acoustical measures improved the noise situation as well as the rated noise experiences better than the organizational measures.

Abbreviations

CAR	Cortisol Awakening Response
CDD	Cortisol Decline over Day
ERI	Effort Reward Imbalance
HPA	Hypothalamic Pituitary Axis
KSD	Karolinska Sleep Diary
KSS	Karolinska Sleepiness Scale
MDI	Major Depression Inventory
MI	Myocardial infarction
NIHL	Noise Induced Hearing Loss
SMBQ	Shirom Melamed Burnout Questionnaire
SOFI	Swedish Occupational Fatigue Inventory
VAS	Visual Analogue Scale
WHO	World Health Organization

Enkel sammanfattning på svenska

Avhandlingen baseras på ett samarbete med förskoleverksamheten inom Umeå kommun och har innefattat medverkan från 101 pedagoger i delstudie 1 och 24 pedagoger i en delstudie 2. Studie 1 som redovisas i tre delarbeten, I, II och III, har innefattat personburna och stationära bullermätningar i lekhallar och i matsalar. Påverkan på upplevelser samt hälsoeffekter av ljudmiljön har analyserats via frågeformulär och analyser av kortisol. Kontroll av hörselstatus har genomförts via audiometrisk screening. Studie 1 innefattar analys av bullrets effekter på såväl hörselrelaterad (Delarbete I) som stressrelaterad ohälsa (Delarbete II). Olika typer av åtgärder för att förbättra ljudmiljön och minska den bullerrelaterade ohälsan redovisas i delarbete III. Delarbete IV fokuserar på hur samverkan mellan buller och arbetsorganisation kan påverka den stressrelaterade ohälsan. Genomförda analyser av buller visar på förhållandevis likvärdiga bullerexponeringsnivåer förskolor och avdelningar emellan. Skillnaderna i exponeringsnivåer veckodagar emellan var små, skillnader mellan individer var däremot stora. Påtagliga skillnader i exponeringsnivåer förelåg som väntat under arbetsdagen. I synnerhet den personburna bulleranalysen pekade på en bullerexponering med påtagliga inslag av variation och transienter i exponeringen. Ljudmiljön karaktäriserades av medverkande pedagoger som den enskilt mest besvärande arbetsmiljöfaktorn. Barnens röster och ljud från deras aktiviteter klassificerades som de mest besvärande bullerkällorna. Personalen uppvisade sämre hörtrösklar för samtliga testade frekvenser jämfört med svensk ej bullerexponerad referenspopulation. De försämrade hörtrösklarna var relativt låga och föranledde inte i något fall remittering till hörselklinik. Prevalensen för tinnitus var 31 %, vilket motsvarar en överfrekvens på 15-20 %, jämfört med svenskt normalvärde. Ljudtrötthet efter arbetsdagens slut utgjorde ett uttalat symptom bland pedagogerna liksom försämrad sömnkvalitet och förhöjd sömnighet vid uppvaknande. Analyser av arbetsbelastning baserat på skattning och kortisolmätningar, indikerade höga energiuttag under arbete och inslag av utpräglad stress, och i flera fall utbrändhet. Signifikanta samband mellan upplevd dålig ljudmiljö, maskering av tal, försämrade förutsättningar för det pedagogiska arbetet och därmed ökad ohälsa kunde påvisas. Ljudmiljön, såväl nivåer som fluktuationer påverkades på ett uttalat sätt av antalet barn på avdelningen. Detta utgjorde också den enskilt viktigaste faktorn för att förbättra såväl ljudmiljön som den till ljudmiljön relaterade hälsan. Akustiska åtgärder visade sig genomgående mer framgångsrika för att förbättra ljudklimatet än organisatoriska åtgärder.

Original papers

This thesis is based on the following papers, which are referred to by their Roman numerals I – IV.

- I. Sjödin F, Kjellberg A, Knutsson A, Lindberg L, Landström U. Noise exposure and auditory effects on preschool personnel. *Noise & Health*, 2012, 14(51):72-82
- II. Sjödin F, Kjellberg A, Knutsson A, Lindberg L, Landström U. Noise exposure and stress effects on preschool personnel. *Noise & Health*, 2012, 14(59):166-78
- III. Sjödin F, Kjellberg A, Knutsson A, Lindberg L, Landström U. Measures against preschool noise and its adverse effects on the personnel – an intervention study. Submitted for publication.
- IV. Sjödin F, Kjellberg A, Knutsson A, Lindberg L, Landström U. Work related stress and stressors in the preschool environment. Submitted for publication.

Introduction

The preschool in Sweden is one of the largest work places. In 2011 close to 80 000 people worked as preschool teachers or child care workers in the public preschools. The number of children attending the public preschools the same year was more than 380 000 (1).

According to the Swedish Work Environment Authority, the preschools are today one of the dominating work places with high noise levels among women (2). They also report that noise, along with problematic psychosocial work factors is a large work environmental problem in Swedish schools (3). During the years 2002 to 2005 almost half of all reported noise related work injuries reported by women, came from women working in the preschool or the primary school (2, 4). The risk of developing a hearing impairment in noisy work environments with equivalent noise levels above 80 dBA, such as industrial work places, is well known. Few studies have investigated the noise exposure in preschools. The reports available (5-7) however, do not account for a severe risk of developing a noise induced hearing loss (NIHL).

The noise in the preschool differs from that in traditional noisy work places. This is due to the number of noise sources that consists of voices from the personnel and mostly from the children. Other sources of noise in the preschool are footsteps, drying cabinets, washing machines, falling chairs and ringing telephones. These can be compared to the more isolated and stable noise sources found in industrial environments.

A main concern regarding noise in the preschool, besides the possible risk of developing hearing related disorders, is the work needed to be carried out. The preschool is a pedagogical work place where the main purpose is to educate and transfer knowledge to help the children in their cognitive development. This work is highly dependent on communication between the preschool teachers, child care workers and the children.

The combination of noise and complex work tasks increases the risk of annoyance since the noise is in conflict with the demands of the work, primarily with the communication aspect. It has been shown that noise interferes with speech intelligibility (8, 9) and also has negative effects on learning (10, 11). By interfering with the work tasks, noise increases the work load, and may, thereby, lead to stress reactions (12-14). An acute stress reaction is seldom hazardous for the individual as long as time for recovery is given. If not, chronic stress may be developed, associated with several

indicators of ill health such as fatigue, sleep disorders, depression, burnout and myocardial infarction (MI) (15-18).

The high number of reported hearing related disorders as well as to what extent the noise has an impact on the psychological well-being needs to be addressed.

Noise

Noise is described as “any unwanted sound that may adversely affect the health and well-being of individuals or population” (19). What constitutes noise of course differs between people due to the individual’s sensitivity to noise and situational factors. Soames (20) showed that this sensitivity can be divided into at least two types of sensitivity: sensitivity to loud noises and sensitivity to sounds causing distraction. Studies have shown that individuals with a low noise sensitivity and a stable personality better cope with noise in complex work tasks (21).

Usually sound is measured as sound pressure level by use of sound level meters. When measuring occupational noise, stationary microphones in the work area are usually mounted. Further ways of measuring occupational noise is the use of a noise dosimeter that is mounted on the worker and carried during the working day.

The measurements made of occupational noise are often described in terms of equivalent dBA or L_{Aeq} , which is the average dBA sound pressure level during the period of measurement. The A in dBA refers to the filter used in the measurement. The main reason for using the A-filter is that the human hearing is not equally sensitive for all frequencies. Our sensitivity to low frequency sounds is poorer than to mid and high range frequencies. The A-filter takes this into account and gives less weight to low frequency parts of the sounds than to the high frequency parts. When measuring occupational noise it is often stated and recommended to use equivalent A-weighted sound level (22).

Since the decibel scale is logarithmic an increase of 3dB corresponds to a doubling of the sound energy. However, a difference in 3 dB is often hardly perceived by humans, and an increase with about 10 dB is required to double the perceived sound level.

Noise exposure among preschool personnel

Few studies have investigated noise exposure of the personnel working in preschools. Previous research has most often focused on the effect of external noise sources on the children (10, 11, 23-25). It also has been reported that the sound level in the preschool during an eight hour working day seldom exceeds the upper occupational limit of equivalent noise level of 85 dBA (5). A lower limit at 80 dBA is also set. When exceeded, measures have to be taken. These occupational limits are applied by many European countries including Sweden. Studies in Swedish preschools have shown that the noise levels normally do not exceed the occupational limits (6, 7). The equivalent noise level in the Swedish preschools range from 64 – 80 dBA. The risk of developing a NIHL thus should be rather low. Despite this, there are indications that hearing impairments for preschool personnel have increased (4).

Beside the occupational upper limits set by the Swedish authorities, recommendations regarding noise levels for different work tasks are set. For work demanding high levels of concentration or work dependent on undisturbed communication such as in teaching, the maximum equivalent sound level recommended not to exceed is 35 - 40 dBA during the working day. However, in this measurement the contribution to the sound level from the employees' and the children's activities should not be included.

The noise levels in the preschool are problematic considering the work needed to be carried out. With a noise consisting mainly of the children's voices and their activities, the noise is characterized by high levels of fluctuation and in the frequency range of speech.

Health

The effects of the complex noise exposure in the preschool make the risk of physiological hearing disorders such as noise induced hearing loss (NIHL) and tinnitus apparent. The risks of developing psychological disorders are also highly pronounced.

Much research has been carried out regarding traffic noise and airport noise and its effect on health and cognitive functions (10, 11, 26-28).

Some studies propose that there is a link between traffic noise and MI (26, 29-31). Airport noise has been shown to increase the risk of hypertension (32, 33), but also increase the risk of sleep disturbance and other psychological problems (34). A possible mechanism that might explain why

noise may lead to hypertension and other psychological disorders is stress. A stress reaction leads to an activation of the hypothalamic-pituitary-axis (HPA). As a result, the body increases the production of cortisol from the adrenal cortex (35). A stress reaction is, however, not usually harmful, but when the stress becomes chronic and no time for recovery is possible, the risk of developing different health disorders is pronounced.

Physiological effects of noise

High noise exposure at work is well known to increase the risk of developing a NIHL. Noise exposure however does not only increase the risk of developing NIHL, it also increases the risk of other hearing related disorders such as tinnitus and hyperacusis.

The prevalence of tinnitus in the general population is approximately 10-15% (36-38). It is common that an individual with a hearing loss also suffers from tinnitus (39, 40). An investigation in the county of Umeå regarding tinnitus in preschools teachers, conducted by a company health care centre, speaks for an overrepresentation of tinnitus.

Another hearing related disorder is hyperacusis, a disability often seen in conjunction with tinnitus (41). Individuals suffering of hyperacusis, experience oversensitivity to sounds that usually are not disturbing for normal hearing individuals. This disability can have a severe negative effect on the sufferers' daily life, at work and during spare time. People suffering from hyperacusis also become more tensed when exposed to high sound levels (42).

Another, however, more uncommon hearing disorders is diplacusis. Diplacusis is a change in perception of sounds (43). Most common is binaural diplacusis, a disorder that make the sufferer experience pitch changes when listening to tones (44). Even more uncommon is monaural diplacusis, a condition that make the sufferer experience one single tones pitch as two different tones. As with tinnitus this hearing disorder is most often seen in patients with a hearing loss (45).

Psychological effects of noise

Working in high noise levels, especially in environments with complex work tasks and with high demands on spoken communication, make the work difficult and more stressful.

A complaint often reported after working in noisy environments is noise fatigue (46, 47). Individuals experiencing noise fatigue usually try to avoid noise sources of all kinds such as listening to the radio or playing music. The noise fatigue usually declines with time after leaving the noisy environment. Nevertheless, experiencing noise fatigue affects the spare time in a negative way and may also affect other people in the same household.

Noise can also lead to a stress reaction by just being highly unpleasant. It can also increase the work load by making the work more difficult to execute. In experimental studies it has been shown that employees exposed to high noise levels, work slower and more irregular than in low noise exposure (12).

The noise in the preschool mainly consists of speech from the children's voices. Research has shown that irrelevant speech puts a larger cognitive load on the workers than other types of noise (9). The masking of speech that occurs in noisy environments, such as in the preschool, puts higher demands on speech perception and increases the mental work load. The masking effect of noise also increases the risk of negative effects on the speakers' voice when trying to make oneself heard. This is especially a problem among people engaged in a pedagogic environment where the voice is the most important tool at work (48, 49).

A further distinction between meaningless noise and noise in the preschool, besides the irrelevant speech, is that the noise in the preschool also contains information of the activities of the children. A falling chair or a crying child cannot be ignored due to the responsibility in the care taking of the children, thus causing distraction. The increased risk of distraction, masking of speech and increased annoyance all contribute to a higher work load (8, 50).

Studies in preschools have shown that teachers with high noise levels at work also experience high interpersonal strain and high stress (51). The disturbance and the sensitivity to the noise has also been shown to be dependent on the personality (21). Interestingly, it is a rather common belief that individuals over time will adapt to noise and thus become less annoyed or disturbed. Research has rather indicated the opposite, that the longer you work in a noisy environment the more disturbed you will be (52).

The link between noise and elevated stress levels has been shown in several studies using cortisol as a marker of stress. Higher noise levels seem to be associated with higher levels of cortisol being released by the adrenal cortex (30, 53, 54). Babish has suggested that the release of cortisol due to noise may be a mediating factor to develop cardiovascular disease (14). Selander (28) made the same conclusion as Babsich when she showed that women

exposed to aircraft noise had an increased morning concentration of cortisol. She suggests that this in turn may be of interest when investigating the effects of noise on cardiovascular disorders. Bigert (55) points out that the use of cortisol as a marker of noise induced stress is reliable and useful when investigating the effects of noise on a group level.

What is known is that long term stress is associated with increased fatigue, depression, sleep disorders, hypertension and increased risk for MI (15-18). It was shown that about 20% of teachers in Sweden do not get the recuperation needed, and that they also had an increased risk of ill health and more absence due to sickness (56). With a high work load and high stress, the need for recovery is crucial.

Stress has also been shown to be associated with cardiovascular disease and impaired sleep. Benham's stress – health model presented in 2010 (57) was strengthened when sleep quality was added to the model. High levels of cortisol were also shown to be associated with disturbed sleep (15). In patients suffering from occupational burnout, it was shown that they also suffer from impaired sleep and that sleep is a vital component in developing burnout (58). Söderström (59) showed that insufficient sleep, less than 6 hours of sleep per night, in combination with high work demands and having trouble not thinking about work during leisure time, increases the risk of developing burnout.

It has also been suggested that depression may be the result of work related long term stress (60). Other studies have shown inconclusive results regarding work related stress and depression (61).

Preventive measures

Traditionally, when applying noise reduction measures in noisy environments such as in industrial work places, focus has been on the noise source. To lower the sound level different approaches can be applied, such as replacing the machine or dampening of the machine to minimize the sound propagation (62). If not successive, the alternative is to provide the employees with hearing protection, i.e. earmuffs or plugs.

The primary noise source in the preschool is the children. In this case a different approach concerning noise dampening is needed since the children themselves are not static sources. Considering the voices and playing activities of the children, these are not always to be described as noisy sounds. As previously described noise can be defined as unwanted sounds. In the case of sound from the children, we normally consider these sounds as

wanted or necessary for the development of the children and the pedagogic process in the preschool. Besides noise sources and with noise from different types of activities in the preschool the sound environment is rather complex. A traditional technical approach such as in industries is not possible in the preschool (63, 64). Concerning aspects of the pedagogic work, with high demands on verbal communication, alternative noise reduction measures are needed. The use of hearing protection such as ear muffs or plugs is in strong conflict with the pedagogic work being carried out. Alternative types of measures therefore need to be applied (65).

Aims of the thesis

Overall aims

The overall aim of the thesis was to clarify the noise exposure in preschool environments and how the exposure interferes with well-being and ill-health of the employees. An overall aim was also to clarify the way in which the noise environments can be improved by different types of acoustical and organizational measures.

Specific aims

The aim of paper I was to describe the noise exposure of the preschool personnel, specific noise sources and their characteristics, especially sound level variability. A further aim was to analyze the noise and its association to the prevalence of hearing impairment, tinnitus, hyperacusis, sound fatigue, masking, voice effects and annoyance.

The aim of paper II was to analyze the presence of stress-related health problems, fatigue, sleep and sleepiness among preschool employees and the way in which these reactions are related to noise and other work related parameters.

The aim of paper III was to analyze the effects of different noise preventive measures and their effects on sound levels, transients and the subjective experiences of noise and health. An aim was also to analyze to what extent the effects of the measures relied on the contribution from the personnel.

The aim of paper IV was to describe and analyze the major work interfering factors in the preschool and the way in which these factors interfere as stressors. A specific central aim was to clarify the role and power of noise and communication overload as a stress factor during work.

Methods

Papers I, II, III and IV

Papers I, II and III are based on data collected in study 1 named “Noise in the preschool – ill health and preventive measures”. In Study 1, data were collected from 101 preschools teachers and child care workers before and after the introduction of measures in each department. Paper IV is based on data from study 2, a follow-up study named “Workload and stress in the preschool – ill health and its relation to the work environment”. In study 2, 24 participants from study 1 was recruited, thus using a nested case – referent study design. In Figure 1, the different data collection periods from the two studies are illustrated. The figure also shows from which data collection period the four different papers presented in the thesis are based.

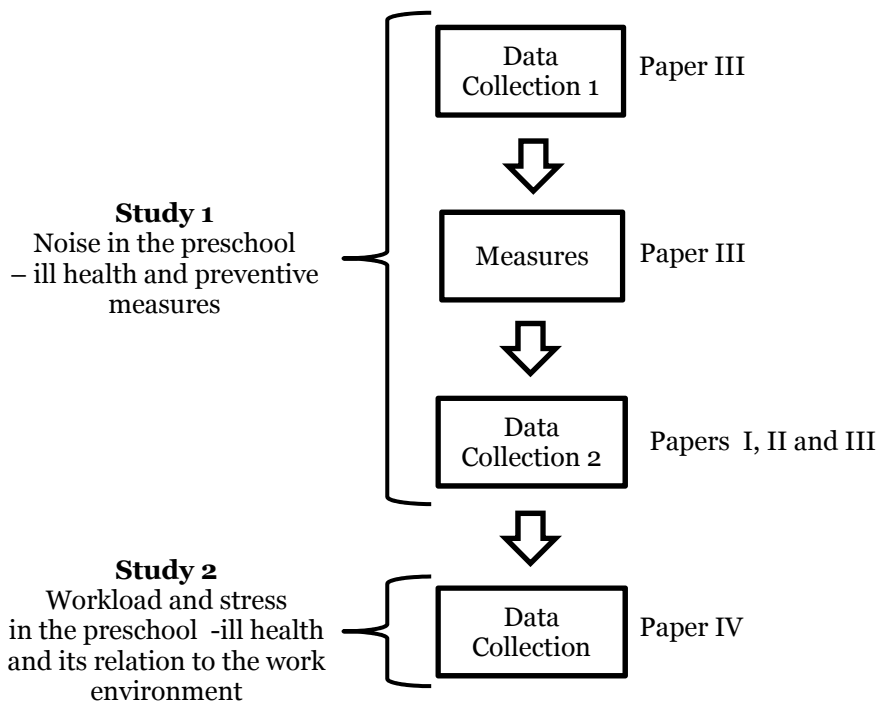


Figure 1. Illustration of the two studies and the data used in the four papers presented in the thesis.

An overview of the different types of measurements included in the papers is described in Table 1.

Table 1. Overview of the methods used for data collection throughout the four papers included in the thesis. Regarding the abbreviations in the table, see the “Abbreviation” section at the beginning of the thesis.

	Study 1			Study 2
	Paper I	Paper II	Paper III	Paper IV
Participants	N = 101	N = 101	N = 89	N = 24
Noise recordings				
<i>Individual</i>	X	X	X	
<i>Stationary</i>	X	X	X	
Audiometric screenings	X			
Saliva Cortisol		X	X	X
Preventive measures			X	
Interviews				X
Observation study				X
Questionnaires				
<i>Work environment</i>	X	X	X	X
<i>Health</i>	X	X		
<i>Hearing</i>	X			
<i>Stress-Energy</i>		X	X	X
<i>SOFI</i>		X	X	X
<i>SMBQ</i>		X	X	X
<i>ERI</i>		X	X	X
<i>KSS</i>		X	X	X
<i>KSD</i>		X	X	X
<i>MDI</i>		X	X	
<i>Work/Demand</i>				X
<i>Stressors at work</i>				X
<i>Work and organization</i>				X

Participants

Participants, papers I and II

The local school authorities invited all preschools in the same municipal area (n=64). Seventeen preschools volunteered to participate in the study. In each preschool, two departments were given the opportunity to participate. Departments with planned changes regarding the staff or with planned physical or organizational changes were excluded.

Employees who met the criteria to participate (working at least 30 hours per week, employed as a child care worker or preschool teacher, not being temporary staff) were invited to participate. As a result, 101 subjects were included in the study with a mean age of 41.0 years (SD 10.0). The study population included 87 females with a mean age of 41.5 years (SD 10.0) and 14 males with a mean age of 38.7 years (SD 10.5).

Participants, paper III

The same participants participated in data collection 1 and 2 in Study 1. However, due to drop outs during the time between the two measurements the total number of subjects was reduced. Eighty-nine subjects, with a mean age of 41.9 years (SD 9.9), 77 females with a mean age of 42.3 (SD 9.8) and 12 males with a mean age of 39.8 (SD 11.0) were used in the analyses of paper III.

Participants, paper IV

Paper IV is based on data from a follow-up study (study 2). A smaller number of participants (n=24) in paper IV were recruited from study 1. Twelve departments were given the opportunity to participate. The aim was to include six departments characterized by high levels of burnout and stress and six departments characterized by low levels of burnout and stress. A burnout/stress index was created using the mean scores regarding burnout and stress from data collection 2 in Study 1. The low burnout/stress departments had a mean index score of 2.4 (SD 0.37), whereas the high burnout/stress departments had a mean index score of 4.1 (SD 0.51). The burnout/stress index was used to rank the departments.

Initially, the departments with the lowest scores were invited to participate. If the department was not able to take part in the study, due to too few employees left from study 1, the department with the closest burnout/stress

index score was invited. This was repeated until six departments with low burnout/stress index scores were included. The same procedure was carried out to include six departments with the highest burnout/stress index scores.

Only women were invited to participate due to the few men employed in the departments included in the previous study. In total, 24 women participated in the study with a mean age of 43.5 years (SD 9.9). All subjects worked full time (40 hours per week).

Noise recordings

Individual noise recordings, papers I, II and III

Sound exposure was measured using individual recordings all working hours during the study week before and after the introduction of the different measures. Two types of noise dosimeters were used in the study, a Brüel and Kjaer 4445 and a Larson Davis Atex-706. The dosimeters were set to log equivalent dB(A), maximum dB(A) and peak value dB(C) each second. All equipment were calibrated each week using a Brüel and Kjaer sound calibrator Type 4231. The participants were instructed orally and by use of a manual in how to mount and handle the equipment.

A laboratory test was made before the start of the study to test different microphone positions of the noise dosimeter (66). The aim was to find a position of the microphone with the lowest speech contribution from the carrier. Three possible microphone positions were evaluated - above the ear, on back of the head and on the shoulder. The result of the study showed that the position with the microphone on the back of the head had the lowest speech contribution, while still giving an accurate measurement of the sound level (66). This position of the microphone was therefore applied throughout study 1.

Stationary noise recordings, papers I, II and III

Stationary recordings were made in each participating department using a Brüel and Kjaer 2260 Investigator. An external microphone was placed approximately at 2 metres height in the centre of the room. The noise levels were recorded in two types of rooms - dining rooms and play halls. The first room was recorded from Monday to Wednesday and the second room from Thursday to Friday. During Monday the recordings were made between 09:00 am and 09:00 pm to also capture the background noise in the department during hours of no activity in the evening. All other days were recorded from 06:00 am to 06:00 pm. The instruments were set to log

equivalent dB(A), maximum dB(A), minimum dB(A) and dB(C)peak. Fast settings were used and the range of the instrument was set to 40-120 dB(A).

Sound fluctuation was evaluated using logged values from the Larson Davis 706-Atex dosimeters. The instrument logged the highest sound level each second during the measurements. The logged seconds with a value higher than 85 dB(A) was considered as a large deviation from the average noise level, and thus considered to be an indication of noise fluctuation. Start and end time of each measurement, that was not fully 60 minutes was extrapolated to a full hour using the number of logged values above 85 dB(A) divided by the number of minutes recorded for the actual hour multiplied by 60.

Audiometric screenings, paper I

All participants were tested using audiometric screenings before the start of the study. No audiometric screenings were older than two years before the start of the study. The screenings were made by a company health care nurse on both ears, using earphones, in a quiet room in the preschools. The tested frequencies were 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 3000 Hz, 4000 Hz, 6000 Hz and 8000 Hz, with a sensitivity of 0 dB or 10 dB. If the tested participant had a deviation between ears, a change in the hearing threshold larger than 10 dB or a decline in hearing compared to a previous screening, they were remitted to an audiometric clinic for further tests.

Saliva cortisol, papers II, III and IV

Saliva cortisol was collected in the middle of the week (Wednesday) during four different time points (at wake up, 1h hour after wake up, 11:00 am and 09:00 pm) by use of saliva sampling kits (Salivette, Nümbrecht, Germany). All participants were thoroughly instructed, both verbally and by use of a manual, about the sampling procedure. The participants were instructed not to eat, drink, use any tobacco or brush their teeth for at least 30 minutes before leaving the sample. The two morning samples were brought to a refrigerator in the preschool as soon as possible. The evening sample was stored in the participant's refrigerator at home and brought to the refrigerator in the preschool the next day. All samples were collected at the end of the study week by the project group and were then stored in a freezer (-20 Celsius) before being sent to a laboratory for analyses. The cortisol samples in papers II and III were analysed at Stockholm University, Stress Clinic with Orion Diagnostica Cortisol RIA procedure (67). The cortisol samples in paper IV were analysed at the department of Clinical Chemistry

at Linköping University with Enzyme Immunoassay (EIA) analyses with a range between 0.3 – 800 nmol/L.

By use of the analysed cortisol, the Cortisol Awakening Response (CAR) and the Cortisol Decline over Day (CDD) were calculated. The CAR value was obtained by calculating the difference between the cortisol values of the two morning samples. The CDD value was obtained by calculating the difference between the highest cortisol value of the two morning samples (usually the second sample) and the cortisol value from the evening sample.

Preventive measures, paper III

Different preventive measures with the aim to lower the sound level or improve the sound environment in the different preschools were introduced in 14 of the 17 participating preschools. One type of measure was introduced in each of the two departments in each preschool. A reduction in number of children in the department was tested in two preschools. Three preschools participated as control preschools and underwent no changes.

By only introducing one specific measure in each preschool the obtained result can be connected to the actual measure. Reliability and validity of the design were followed up throughout the study period. The participating preschools were told not to introduce any physical or organizational changes that might interfere with the tested measures. The adaptation to the instructions and conditions was controlled during the repeated visits in the preschools. No deviations from the given instructions were identified during the study.

The implemented measures were characterized as either acoustical or organizational measures.

Acoustical measures

The acoustical measures were passive installations with little need of engagement from the personnel. The aims of the measures were either to lower the sound level or improve the sound quality in the department. Six different types of acoustical measures were applied in the study.

New ventilation system

In one preschool the ventilation system was rebuilt with an aim to lower the low frequency background sound. The background sound level in the two participating departments were reduced from 31 dB(A) (7.14) to 28 dB(A)

(SD 3.16). The measurements were made in the evenings with no activity going on in the preschool.

New tables

Old tables with a hard wooden surface were replaced in one preschool with new dampened tables (Balzar Beskow AB, Sweden). The new tables had a surface constructed with a softer noise damping material. The purpose of the new tables was to reduce the noise generation from different activities such as periods of eating including noise from forks, plates and falling glasses, but also from playing activities at the tables with different toys.

Noise isolation wall panels

Two departments in one preschool were equipped with noise isolation wall panels (Wall panel C/Texona, Saint-Gobain Ecophon AB, Sweden) in the dining rooms and the play halls. The panels had an absorption factor of α_p 1.0 in the frequency range of 500 – 1000 Hz and α_p 0.9 in the frequency range 1000 Hz to 4000 Hz according to the SS-EN ISO 11654 classification.

New toys

Toys found to be noisy by the personnel and the research group were replaced with new toys with a lower sound level. About 10-15 toys were considered to be noisy in terms of high sound levels and transients. The new toys introduced in the departments (Lekolar, Sweden) were made with dampened materials such as rubber wheels instead of plastic wheels, building blocks made of foam material instead of wood, etc.

Reduced number of children

At two preschools and in two departments per preschool the number of children was reduced by two. In one preschool the number of children was reduced from 24 to 22 children in one department. In the other department the number of children was reduced from 18 to 16. In the second preschool the number of children was reduced from 17 to 15 in both departments.

New play hall

A large play hall shared by two departments in one preschool was rebuilt to give the personnel the opportunity to divide the children into smaller groups. The new play hall was rebuilt into four smaller playing spaces instead of one large room.

Organizational measures

At seven preschools different measures with an organizational approach was implemented. The organizational measures needed a higher degree of commitment from the personnel in order to be fully implemented. The aim of the organizational measures was to lower the sound level and improve the sound quality in the departments, but also in some cases to reduce the stress and work load.

Recovery room for the children

At one preschool, one room in each department was altered into a relaxation room for the children. The ceiling was covered with cloth and a sound speaker system for playing relaxation sounds (e.g. music, whale sounds, bird sounds, etc.) was installed. The lights in the room were replaced with an option to be able to dampen the light. Furthermore, light projection equipment was installed to produce slowly moving colourful abstract illustrations on the walls in the room. Projections of butterflies, spots and clouds were also made possible by use of another projector. The personnel were instructed to use the room in the afternoon or during other periods when they thought the children needed a rest.

Recovery room for the personnel

In one preschool a new room for recovery for the personnel was arranged. The room had a background sound level lower than 40 dB(A) and had a comfortable chair with footrest and adjustable soft light. The participating personnel were instructed to use the recovery room every work day. They were instructed to use the room two times per day for at least 15 minutes at each occasion. When the personnel had rested they noted their rest on a checklist.

Regulation of the light

In two departments of one preschool a new lighting system was installed. In the dining room, play hall and other areas used by the children, the fluorescent light was made possible to dampen. The personnel were instructed to use the possibility to dampen the lights during activities with the children such as eating and resting, and increase the lights when engaged in educational activities.

SoundEar

Three SoundEars (SoundEar A/S) in each of the two participating departments in one preschool were installed. The sound ears were installed in the play halls, the dining rooms and the entrance halls. The sound ears were calibrated to give a yellow light signal at sound levels above of 65 dB(A) and a red light signal at sound levels above 70 dB(A). The aim of installing the sound ears was to raise the personnel awareness to lower the noise levels. The personnel were also instructed to educate the children about the purpose of the sound ears. The children were also repeatedly told to observe the sound ears and lower their voices if the sound ear signalled red.

Noise and risk education for the personnel

In one preschool a noise and risk education programme was carried out. Two departments participated in the education covering noise and risks when working in noisy environments, but also about legislation and preventive measures. The education was mainly carried out using distance education through email with reading materials sent out. A small library was also set up and oral lectures were conducted in conjunction with staff meetings. The education was ongoing for about nine months.

Noise education for the children

An education programme about noise for the children was carried out in the departments in one preschool. The aim of the education programme was to teach the children what noise is, how it affects their ears and health, and why it is important not to scream and shout loudly. The education was carried out in connection with both indoor and outdoor activities. The pedagogics were carried out together with an external pedagogue (AMMOT, Stockholm) and the education was based on entertaining, songs and practical exercises.

Voice education for the personnel

In one preschool a licensed speech therapist worked with the employees in the departments. The aim of the education was to teach how to use the voice when communicating with the children and colleagues. The education also covered aspects of different voice related impairments, commonly seen among pedagogues (48).

Interviews, paper IV

The working conditions may differ to a higher or lower degree between preschools and the departments. To gain better understanding of the work organization, work environment, etc., and to make decisions about what questionnaires to be used in study 2, semi-structured interviews were made with child care workers and preschools teachers. The interviewed personnel were not participants in study 2. The focus of the interviews were on the daily work in the preschool, mostly concerning the physical work place, leadership, how the work was organized, administration and pedagogical planning. Areas regarding aspects of the child group and support from colleagues were also discussed.

The interviews were conducted individually and in group. Two members of the project group were present during the interviews; one leading the discussion and one taking notes and creating mind maps.

After each interview, the notes and the mind maps were summarized. The aim was to cover all aspects of the work in terms of stress and work load in the daily work. After summary of the first interviews new interviews were made with notes and mind-maps again summarized. When no new topics or aspects of the work came up for discussion, the interviews were finished. The collected data were summarized and used for the creation of questionnaires with a specific focus on stressors, stress and work load in the preschool. The created questionnaire covered four main areas - noise, situational factors at work with high stress, how the work is organized and how the constitution of the child group affects the work being carried out.

Observation study, paper IV

Communication is a central part of the work carried out in the preschools. An observation study was therefore performed to quantify the communication interaction that occurs between the children and the personnel and between the personnel.

Each participant in the study was observed during two sessions on one representative work day. The first session covered 60 minutes before the lunch serving (10:00 am to 11:00 am), and the second session covered 30 minutes during the lunch serving (11:00 am to 11:30 am). The observer arrived approximately 30 minutes before the first session in order to gain acquaintance with the personnel and the children in the department.

The observer followed the participant during the two sessions and was instructed to count the number of communications to and from the observed participant. Each time the participant communicated with a child and each time a child tried to communicate with the observed participant were noted in a protocol. The same was done for the communication between the observed participant and her colleagues. The observer also noted the number of the times the participant made a visual control of what was going on in the department. Furthermore, the observer also noted the number of “problematic” situations. A problematic situation was defined as children crying, fighting or otherwise needing support from the participant.

After the observation period the observed participant was instructed to fill out a questionnaire with six questions regarding how stressful they found different aspects of the work carried out during the observation. The questions were stress ratings related to the observed communication made by the observer. The questions dealt with the following: to what extent they found the children seeking their attention stressful, to what extent they found their own need to seek the children’s attention as stressful, to what extent they found their colleagues seeking their attention as stressful, to what extent they found their own needs to seek their colleagues attention as stressful, to what extent they found eventual problematic situations was stressful, and to what extent they found their need to do visual checks to have control over the children as stressful. The questions were answered using a visual analogue scale ranging from 0 mm (not stressful at all) to a 100 mm (almost unbearable stressful).

Furthermore, using the same scale they the participants were also asked to what extend they found being observed was stressful. Questions were also asked about whether the behaviour of the children differed due to the presence of the observer or not (calmer or more excited than usual).

A question was also asked whether the observed participant thought the observation period could be considered to be representative for a normal working day in the department. This was assessed using a 1 to 5 scale (1 = yes, 2 = no, today was a little more calmer than ordinary, 3 = no, today was much more calmer than ordinary, 4 = no, today was a little more stressful than ordinary, 5 = no today was much more stressful than ordinary).

Questionnaires

Work environment, papers I, II, III and IV

The work environment was evaluated by use of questions regarding different aspects of work such as lighting, indoor climate, ergonomics, sound level, sound sources and sound quality. Questions were also asked about systematic work environment management.

Health, papers I and II

Questions were asked regarding personal health such as headache, shoulder problems and chest pains for the last 30 days. The prevalence of the described symptoms both during work and in spare time was assessed by the participants. Questions were also asked regarding whether they used any prescribed medication.

Hearing, paper I

Hearing impairment was evaluated using questions ranging from no problems to strongly impaired. If the participants experienced any impairment regarding hearing, further questions were asked regarding use of hearing aids, discomfort and attention in various noisy situations.

Tinnitus was assessed with questions of prevalence and how the tinnitus was experienced (both ears, left or right ear, or other experiences). If the participant experienced tinnitus, further questions were asked regarding when and how often the tinnitus was experienced and the degree of discomfort.

Sound distortion was assessed in a similar way as tinnitus.

Hyperacusis was assessed by use of questions regarding prevalence. If the participant experienced hyperacusis a follow up questions concerning degree of discomfort was answered. Several different sound situations were listed and the participants were asked to rate to what degree these situations interfered with their hyperacusis.

Sound fatigue was assessed in a similar way as hyperacusis. Sound fatigue was also assessed as to what extent it had an impact on their spare time.

By use of questions from previous studies (68, 69) noise annoyance was assessed using a visual analogue scale with five verbal anchor points, ranging from 0 mm (not disturbing) to 100 mm (almost unbearable).

Stress-Energy, papers II, III and IV

The psychosocial working conditions and its relation to subjective stress was evaluated using the Stress-Energy adjective checklist (70). The questionnaire measures the subjective experience of stress and energy at the time of answering. The participants answered the questionnaire at four different time points (at wake up, one hour after wake up, at 11:00 am and at 09:00 pm). The questionnaire was based on twelve items rated on a scale from 0 to 5 (0 = not at all, 1 = hardly any, 2 = to a little degree, 3 = to some degree, 4 = to a high degree, 5 = to a very high degree) (71-74). The mean score for the stress items and the energy items was calculated. For stress, the score 2.4 is considered as the neutral midpoint, and for energy the score 2.7 is considered as the neutral midpoint (18, 75). By combining the two scales four categories were formed, Worn-out (high stress + low energy), Committed under pressure (high stress + high energy), Bored (low stress + low energy), and Committed with no pressure (low stress + high energy). By use of the individual score for the stress scale and energy scale, each participant can be assigned to a category.

Swedish Occupational Fatigue Inventory (SOFI), papers II, III and IV

The experienced fatigue of the participants was evaluated by use of the Swedish Occupational Fatigue Inventory (SOFI) (18, 75). The questionnaire is designed to measure fatigue in five different dimensions, using a scale ranging from 0 to 5 (0 = not at all, 1 = hardly any, 2 = to a little degree, 3 = to some degree, 4 = to a high degree, 5 = to a very high degree). The five different dimensions are physical exertion, lack of energy, physical discomfort, lack of motivation and sleepiness.

Shirom-Melamed Burnout Questionnaire (SMBQ), papers II, III and IV

To assess burnout the Shirom Melamed Burnout Questionnaire was used (SMBQ). The SMBQ evaluates four different subscales: emotional and physical exhaustion, tension, listlessness and cognitive weariness. The questionnaire is based on 22 items ranging from 1 (almost never) to 7 (almost always) with no verbal anchors in between, and a burnout score was

calculated. The score was used to categorize the participants into different burnout groups (76-79).

Effort Reward Imbalance (ERI), papers II, III and IV

The effort at work and the reward received was assessed by use of the Effort Reward Imbalance model (ERI) proposed by Sigriest (80). The model is based on questions answered in two steps. A statement is presented regarding different aspects of the work and the respondents are asked whether they agree or disagreed with the statement. Depending on the answer, the respondent in some cases need to clarify to what extent they found the stated situation as troublesome. Two types of sum-scores were calculated, an effort score and a reward score. The ratio between the two scores was calculated. A ratio value higher than 1.0 was considered to indicate a severe imbalance between the efforts put in and the reward received in terms of material assets and appreciation.

Karolinska Sleepiness Scale (KSS), papers II, III and IV

To evaluate the sleepiness before and after a night's sleep, the Karolinska Sleepiness Scale (KSS) was used (81). The participants were asked to rate their sleepiness before going to bed and their sleepiness at wake up in the morning for all days of the week (papers II and III). In paper IV the participants filled out the questionnaire only on Tuesday, Wednesday and Thursday morning. The ratings were made on a scale ranging from 1 to 9 with verbal anchors on odd numbers (1= very alert, 3=alert, 5=neither alert nor sleepy, 7=sleepy, but with no difficulty staying awake and 9=very sleepy, fighting against sleep, requiring great effort to stay awake).

Karolinska Sleep Diary (KSD), papers II, III and IV

The Karolinska Sleep Diary (KSD) was used to evaluate the sleep quality of the participants (82). The KSD questionnaire measures several aspects of sleep quality with questions regarding number of wake ups, dreams, enough sleep, sleep quality, etc. The used scale is a 1 to 5 scale with different verbal anchors depending on the question asked.

By combining the different questions of sleep quality an index was created regarding disturbed sleep. The mean scores for the questions stress before going to sleep, trouble falling asleep, difficulties falling asleep, sleep quality, premature awakening, disturbed or restless sleep, easy getting out of bed in the morning, time awake during the night, enough sleep, deep or light sleep, and fully rested, were calculated. A high score indicated higher sleep quality.

Reliability analyses were made for the created index using Cronbach's Alpha. The Alpha score in papers II and III was 0.8 and in paper IV the Alpha score was 0.89.

Major Depression Inventory (MDI), papers II and III

Depression was evaluated by use of the Major Depression Inventory (MDI) (83, 84). The questionnaire is based on the WHO ICD-10 algorithms concerning depressive symptomatology (85). The questionnaire is based on eleven questions ranging from 1 to 6 (1 = all the time, 2 = most of the time, 3 = about half the time, 4 = less than half of the time, 5 = small amount of the time, 6 = at no time), and a total score between 0 and 50 is calculated. The score was used to classify the participants into different groups regarding depression severity (84).

Work Demand Control model, paper IV

Psychosocial working conditions was evaluated by use of the Work Demand Control model (86), a model that evaluates the subjective experience of control and demands at work. A low degree of control (possibilities to make decisions at work) and high psychological demands at work may contribute to physiological ill health. A higher degree of control gives the worker better possibilities to cope with high demands at work, thus reducing the risk of developing ill health. The model uses a 1 to 4 four scale (1 = no, almost never, 2 = no, rarely, 3 = yes, sometimes, 4 = yes, often). This scale is used with eleven items and the mean score is calculated. The mean score of the first five items is the Demand score and the Control score is based on the last six items (87).

Stressor at work, paper IV

Several questions were asked regarding stress at work using a visual analogue scale ranging from 0 mm to a 100 mm (0 mm = not stressful at all, 100 mm = almost unbearable stressful). Various situations common at work in the preschool were presented and the participants marked to what extent they found the situations as stressful. The questions were based on information from the interviews carried out. Stressful situations in four different areas of work was evaluated - the organization of the work, noisy situations, work situations and aspects of the child group.

Work and organization, paper IV

The organization of the work was evaluated using a questionnaire based on information from the previous interviews. The design of the questionnaire was similar to the ERI questionnaire. A statement of a working situation in the preschool was presented and the subject was asked to answer whether they agreed or disagreed with the statement. If they considered the statement presented as stressful they were also asked to rate to what extent they found it stressful. The scale ranged from 1 to 5 (1 = no, I do not agree with the statement, 2 = I agree with the statement, but I do not find it stressful, 3 = I agree with the statement, and I find it a little stressful, 4 = I agree with the statement, and I find it stressful to a high degree, 5 = I agree with the statement, and I find it stressful to a very high degree). Questions were asked regarding the organization of the work in the departments, work tasks, leadership and support, premises and different aspects of the child group.

Statistics

All statistical analyses were made using SPSS version 17.0. The methods used in the different papers included in the thesis are listed in Table 2. Comparison of means for normally distributed data were analyzed using independent samples t-tests; non-normally distributed data were analyzed using Mann-Whitney tests. Comparisons of means in Paper III, analyzing the participants before and after the implementation of the different preventive measures were analyzed using paired samples t-test for normally distributed data and Wilcoxon signed-rank test for non-normally distributed data. Group differences were analyzed using one way ANOVA and Chi-square tests. In paper III, group differences were also analyzed using ANCOVA analyses with the number of children as a covariate. Correlation analyses were made using Pearson's correlation coefficient for normally distributed data and Spearman's correlation was used for non-normally distributed data. Linear regression analyses were also used (paper II and III). Reliability analyses using Cronbach's Alpha were made for created indexes in the questionnaires but also for testing the reliability of the sound level measurements for the different days of the week. Level of significance was set to alpha 5% for all analyses.

Table 2. Overview of the statistical methods used for data analyses throughout the four papers included in the thesis.

	Study 1			Study 2
	Paper I	Paper II	Paper III	Paper IV
Independent samples t-test	X	X		
Mann-Whitney test				X
Paired samples t-test			X	
Wilcoxon signed-rank test			X	
One way ANOVA	X	X	X	
ANCOVA			X	
Chi-square	X			
Pearson´s correlation	X	X		
Spearman´s correlation	X	X		X
Linear regression analyses		X	X	
Cronbach´s Alpha		X	X	X

Ethics

The studies included in the thesis were approved by the Regional Ethical Review Board in Uppsala. All participants were informed about the purpose and how the studies were designed. They were also informed that presented data would be anonymous, and that data would only be presented group wise. They were informed that their participation was strictly voluntarily and that they were able to leave the study at any time. All participating employees have given their written consent to participate.

Results

The data from studies 1 and 2 were used in the four papers and the results from the four papers are described under the headings; noise exposure, subjective responses to noise exposure, effects of the noise exposure, interactions and measures.

Noise exposure

The noise exposure was evaluated by use of noise dosimeters carried by the participating personnel and by use of stationary microphones in the dining rooms and the play halls at each department. In general, there were small differences between the preschools and the different departments regarding the average equivalent sound level, both for stationary and personal measurements. Differences in the personal measurements were also small. However, between individuals, larger differences were seen regarding equivalent sound levels, with two individuals exceeding the lower occupational noise level limit of 80 dB(A)_{Leq} and one individual exceeding the higher occupational noise level limit of 85 dB(A)_{Leq} (22).

Personnel recordings

Table 3 gives an overview of the average values of the equivalent sound level for all personnel recordings and all preschools, separated in the different days of the week. Maximum registered equivalent dB(A) sound level is also shown for each work day. Furthermore, the average dB(C) peak values and the highest dB(C) peak values for each work day are described.

The average equivalent sound levels for all work days were quite similar. The highest registered individual equivalent sound level about 85 dB(A)_{Leq}, was registered on Monday. The highest registered dB(A) sound level was 116 dB(A) and the highest dB(C) Peak value was 132 dB(C).

Table 3. Average values and maximum values for the different sound measurement separated by week day. (The similar sound level for dB(C) Peaks during the days of recordings indicates that the registered sound level has exceeded the instrument capacity).

	Mon (n=84)		Tue (n=79)		Wed (n=79)		Thur (n=86)		Fri (n=77)	
	SD	SD	SD	SD	SD	SD	SD	SD	SD	
Mean dB(A)Leq	70.7	3.4	70.5	2.4	70.7	2.3	70.5	2.2	70.3	2.7
Max dB(A)Leq	85.1		81.2		76.7		77.3		79.4	
Mean dB(A)Peak	102.7	5.4	103.6	4.1	103.9	3.9	102.7	3.4	102.8	4.6
Max dB(A)Peak	116.4		114.7		114.0		112.1		114.3	
Mean dB(C) Peak	122.5	6.9	122.7	4.9	122.2	4.9	122.2	4.6	122.1	4.8
Max dB(C)Peak	132.4		132.1		132.1		132.4		132.4	

Stationary recordings

The equivalent stationary sound level recordings were on average 64.1 dBA (SD 2.3) in the dining rooms and on average 64.1 dBA (SD 2.2) in the play halls. The highest recorded sound level in the dining rooms was 104.0 dB(A) and 103.6 dB(A) in the play halls.

Sound fluctuations

The fluctuations of the sound during the working day are shown in Figures 2 and 3. The individual recordings give detailed information about the sound level change over the day, exemplified by one personal noise dosimeter recording in Figure 2. With the dosimeter set to log, the equivalent dB(A) value for each second, a high resolution image of transients is possible. The figure shows the transients that occur during the working day as well as few periods of lower continuous low sound levels.

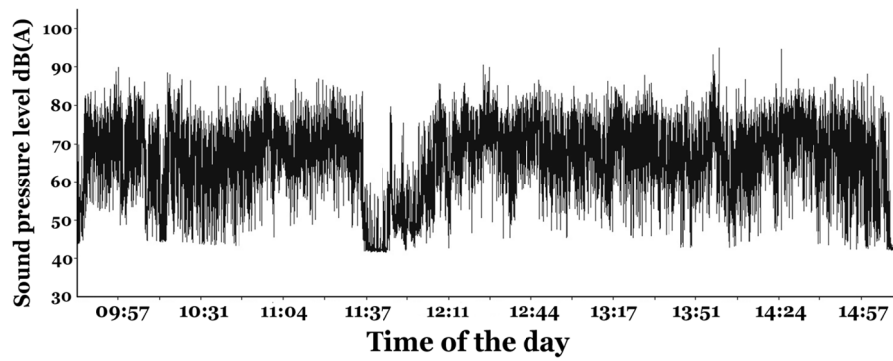


Figure 2. Example of an individual noise dosimeter sound level recording during a working day illustrating the sound level changes using the logged equivalent dB(A) value for each second.

Figure 3 is an example of a sound recording made in the dining room at one department. The sound level meters logged the equivalent sound level each minute and thus gives a lower resolution of transients in the illustration compared to the personal dosimeter in Figure 2. The illustration also shows periods of higher and lower activities in the room. As can be seen from Figure 3 the room was not used until about 07:00 am and with varying sound levels throughout the day. At around 15:30 pm the room was no longer occupied by children or the staff.

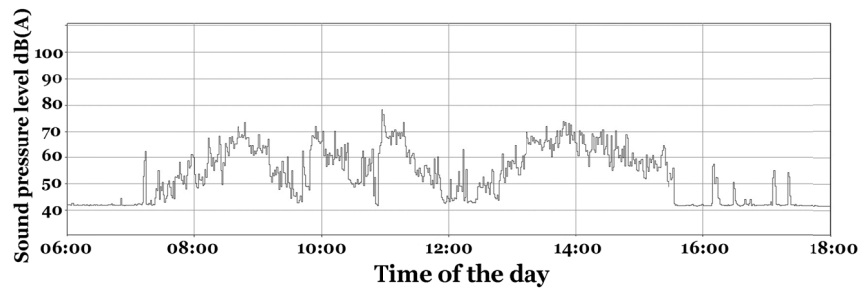


Figure 3. Example of a stationary sound level recording during a working day, illustrating the sound level changes using the logged equivalent dB(A) value for each minute.

In Figure 4 the number of sound events above 85 dB(A) per hour is illustrated, showing that the number of sound events correspond to the activities carried out at the department. In the early morning and at time of rest around 12:00 am to 01:00 pm the number of sound events above 85 dB(A) per hour were reduced.

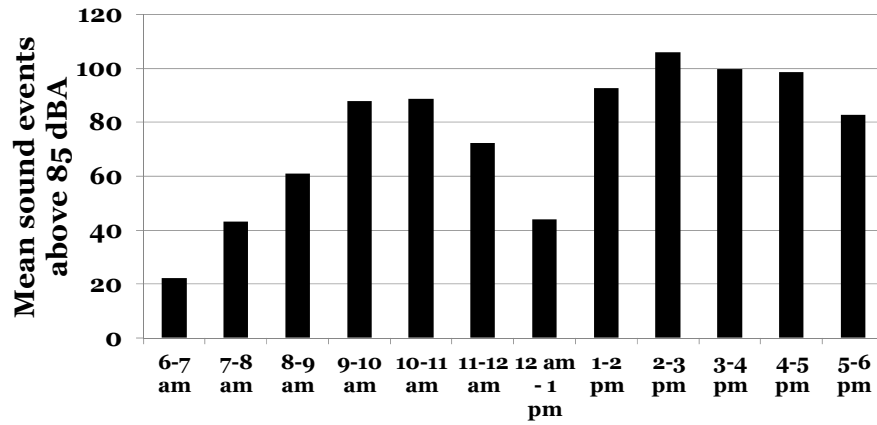


Figure 4. The mean number of sound events above 85 dB(A) per hour registered by the personal noise dosimeters during all work days.

The personnel were also asked to rate to what extent they experienced sudden changes in the sound level at their department. As can be seen from Figure 5 almost half of the employees (48%) experienced sudden changes several times each day. About 17% experienced several sudden changes of the sound level each hour.

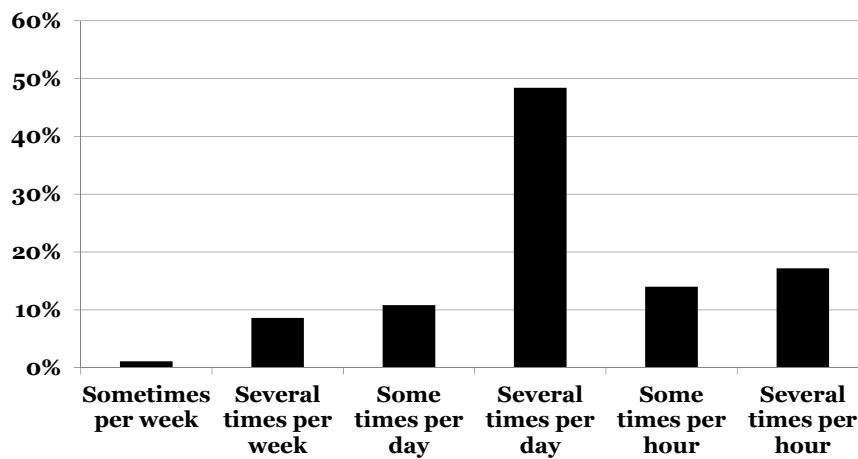


Figure 5. Experiences of changes in the sound environment.

Noise and the impact of number of children

The impact on the sound level of the number of children present at the departments was evaluated. The mean number of children during the study week correlated significantly with the average equivalent sound level in the personal noise dosimeter recordings ($r = .24, P < .05$). Similar results were seen for the correlation between the mean number of children and the average equivalent stationary sound level ($r = .41, P < .01$).

Using data from the first and second data collection periods in study 1 the difference in the mean number of children present at the department and the difference in mean equivalent dB(A) during the work week were calculated. As can be seen from Figure 6, linear regression analysis showed that a change in number of children was associated with the sound level ($r^2 = .26, P < .01$). A reduction of number of children in the second measurement was associated with a lowered sound level, and vice versa.

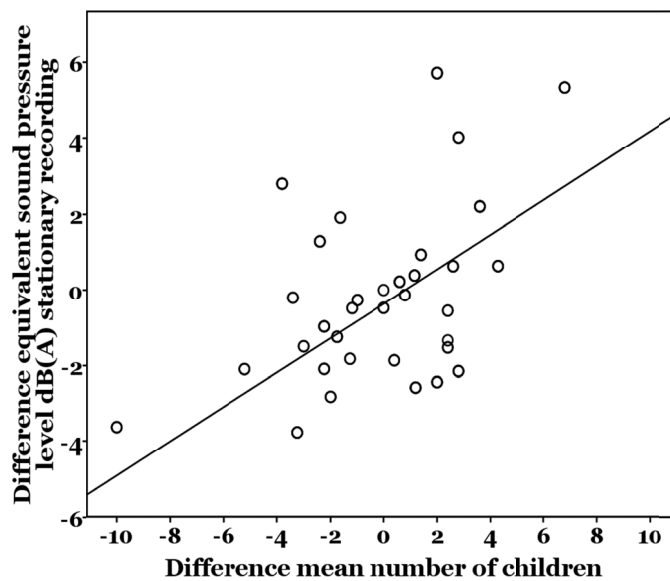


Figure 6. Scatterplot with best fitted line for the linear regression analysis regarding the difference in equivalent sound level dB(A) and the mean difference in number of children at the department between the first and last measurements in study 1.

The correlation between the fluctuation of the noise (the number of sound events above 85 dB(A) per hour) and the number of children was analyzed (Figure 7). The analyses revealed an association between the mean number of children present at the department and the mean number of sound events above 85 dB(A) ($r = .27, P < .05$).

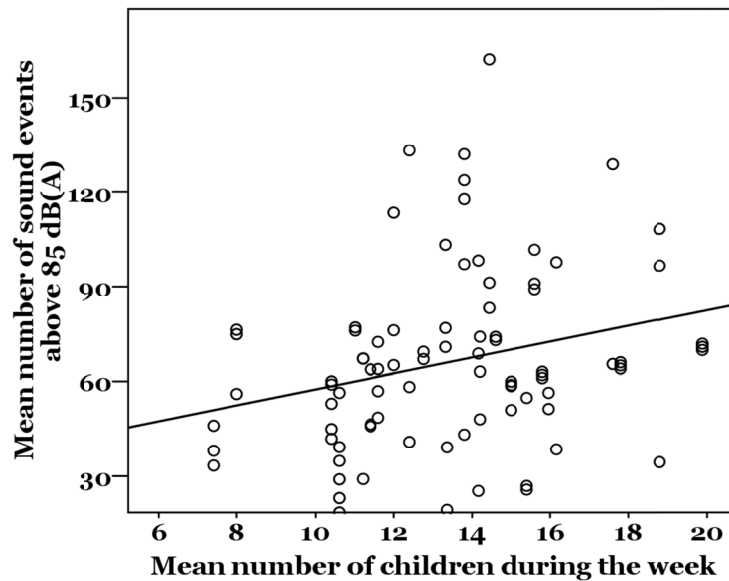


Figure 7. Scatterplot with best fitted line for the correlation of mean number of sound events above 85 dB(A) and the mean number children at the department.

Subjective responses to the noise exposure

The subjective response to the sound environment was evaluated by all participants in study 1. To evaluate the most troublesome work interfering factor, the participants were asked to rate how troublesome they found different work environmental factors as well as rate the most troublesome noise sources at work.

Ranking of work environmental factors

Different environmental factors were rated regarding troublesomeness at work. Noise was the environmental factor rated as being the most troublesome (3.2, SD 0.6) followed by ergonomics (2.8, SD 0.7) (scale 1 to 4).

Ranking of the noise sources

Various noise sources were ranked on a 1 to 4 scale regarding their disturbance at work. The most disturbing noise sources are shown in Table 4. The noise source rated as the most disturbing based on the mean value was the children's voices, and second most disturbing was noise from children's activities.

Table 4. Disturbance ratings of different noise sources

	N	Min	Max	Mean	SD
The children's voices	94	2	4	3.3	0.59
Noise from the children's activities	93	2	4	3.0	0.59
Other sounds deriving from the children's activities	93	2	4	3.0	0.55
Porcelain, cutlery	94	1	4	2.8	0.69
Drying cabinets	94	1	4	2.6	0.73

Effects of the noise exposure and health

The effects of the noise exposure were evaluated by using ratings for noise annoyance and masking effects on communication at work.

Noise annoyance

The participants noise annoyance at work was evaluated by use of a visual analogue scale (VAS) ranging from 0 mm (not disturbing) to a 100 mm (almost unbearable) (Figure 8). The annoying noise at work was rated as "quite disturbing" to very disturbing". No significant associations between noise annoyance and the recorded sound level or mean number of sound events above 85 dB(A) was seen.

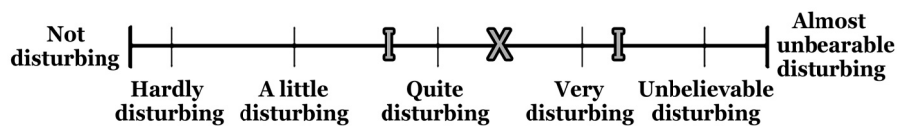


Figure 8. Noise annoyance ratings at work (X=mean, I=SD).

Masking

The masking effect on the verbal communication in the work environment is described by use of evaluations of the possibilities to carry out a normal conversation over the telephone and by ratings of the overall ability to communicate verbally in the preschool. Effects of masking were seen for communication over the telephone. About 24% of the personnel reported difficulties during 50% of the phone calls. Eight-teen percent reported being disturbed during 75% of the phone calls.

Regarding whether the noise affected the possibility for verbal communication at work, about one-third reported disturbance during 25% of the time. Nine-teen percent reported that half of the time at work was affected by masking noise.

No associations were found between the measured sound levels and the reported masking or number of sound events above 85 dB(A). As could be seen from Table 4, the children's voices were rated as the most disturbing noise source. The disturbance from the children's voices was also correlated to rated masking at work ($r = .40, P < .01$). Similar results were seen regarding disturbance of noise from the children's activities and masking ($r = .32, P < .01$).

Hearing impairments

Hearing impairments were evaluated by use of audiometric screenings. The results of the screening are described in Figure 9. The prevalence of hearing thresholds larger than 25 dB for both left and right ears were calculated. Twenty-five dB was used as an indicator of a low degree of hearing impairment (88). The prevalence of reduced hearing thresholds was highest for the frequencies 3000 Hz and above. The highest prevalence of hearing thresholds larger than 25 dB was seen for the right ear at 6000 Hz with a prevalence about 35%.

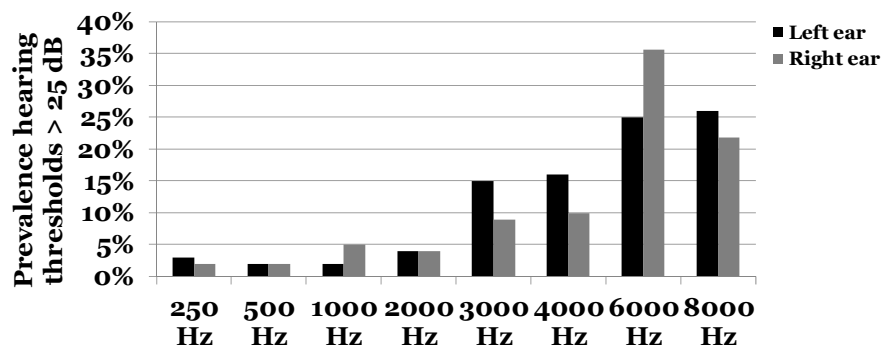


Figure 9. Prevalence of hearing thresholds larger than 25 dB for all tested frequencies of the employees.

When applying the Swedish national criteria in defining a hearing impairment, no participants exceeded the definition (89). Furthermore, no participant was remitted to an audiologic clinic for further testing.

The results of the audiometric screenings were also compared to the Swedish hearing reference data (50th percentile) regarding hearing thresholds (90). As can be seen from Figure 10 the screening thresholds of the employees exceeded the thresholds of the reference material with age matched individuals unexposed to noise at work. Significant group differences were seen for all tested frequencies using Anova analyses ($P < .01$).

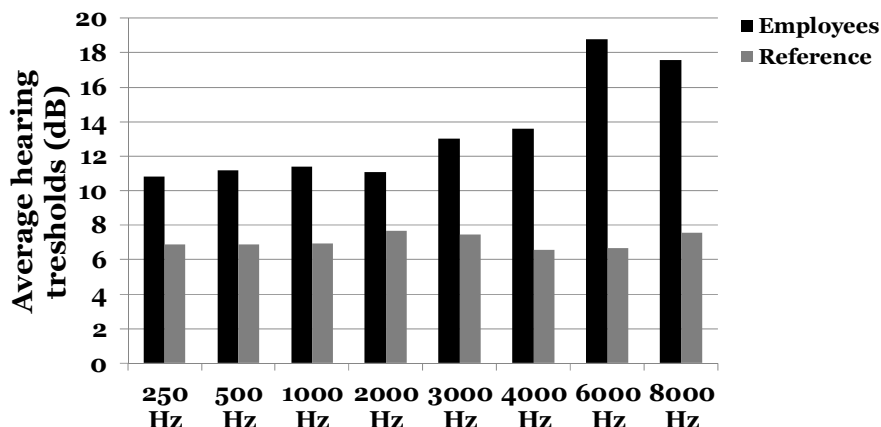


Figure 10. Average hearing thresholds of the employees compared to the reference group.

Significant correlations were seen between the personal recorded equivalent dB(A) sound level and hearing thresholds for the audiometric frequencies 250 Hz ($r = .19$), 1000 Hz ($r = 0.26$) and 2000 Hz ($r = 0.24$), ($P < .05$).

Tinnitus

Tinnitus prevalence was about 31%. In Table 5 the participants are dichotomized between with or without tinnitus. As can be seen, employees with subjectively reported hearing loss also reported to a higher extent symptoms of tinnitus. This is also true when evaluating the results from the audiometric tests. Employees with hearing thresholds larger than 25 dB for any of the tested frequencies also reported to a higher extent tinnitus compared to employees with hearing thresholds better than 25 dB for all tested frequencies.

Table 5. Prevalence of tinnitus separated by subjectively reported hearing status and hearing thresholds > 25 dB for any of the tested frequencies

	No tinnitus (%)	Yes, tinnitus (%)
Subjectively reported hearing		
No reported hearing loss	78.0	22.0
Reported hearing loss	58.1	41.9
Hearing thresholds (>25 dB any Hz)		
No hearing thresholds > 25dB	78.6	21.4
Hearing threshold > 25 dB	60.8	39.2

Sound fatigue

About half of the employees reported sound fatigue sometimes per week. About 20% suffered from sound fatigue after every work day. Five percent suffered from sound fatigue every day including weekends.

Stress

The results from the four time points when the Stress –Energy questionnaire was answered by the employees are shown in Figure 11. As can be seen, most of the employees at wake-up reported low stress and energy (if the rating had been done at work they would be categorized as “bored”). Only 4% reported being highly stressed. One hour after wake up, a majority the employees reported higher energy and higher levels of stress. About 20% reported being highly stressed. At midday, during work, a further increase in energy as well as stress could be seen. About 45% reported working with high stress at 11:00 pm. At 09:00 pm the reported levels of stress were reduced and also energy to some extent; however, about 12 % still reported high levels of stress. No employees were characterized by high levels of stress and low levels of energy (worn out) at any of the four time points.

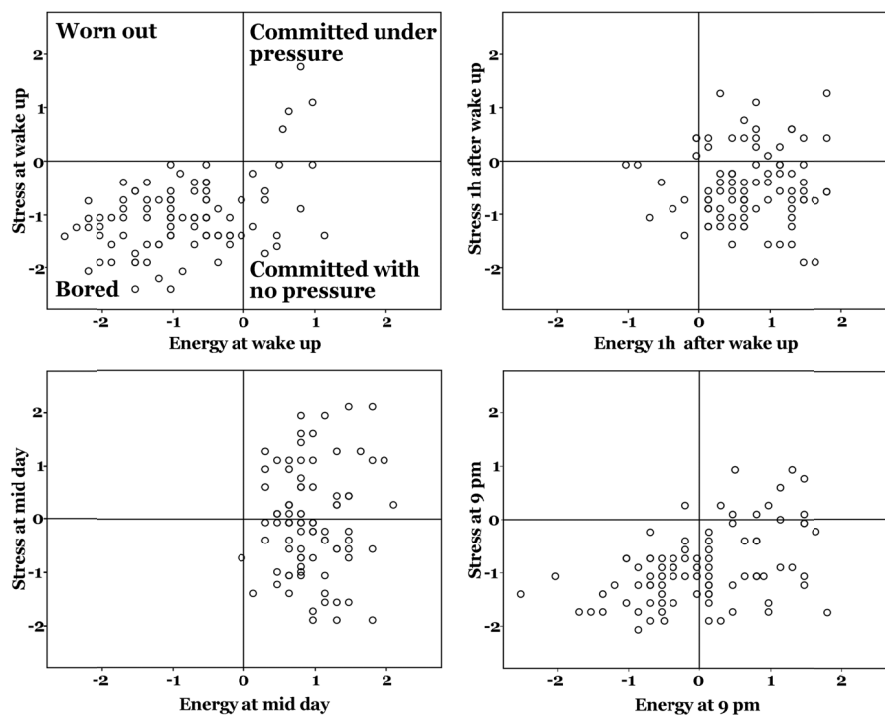


Figure 11. Stress and energy values of the employees during the four times of ratings during the day (upper left = worn out, upper right = committed under pressure, lower left = bored, lower right = committed with no pressure).

Cortisol data

Changes in cortisol levels during the day are described in Table 6. In average the highest cortisol levels were obtained one hour after awakening in the morning with a decline in the levels during the day. The lowest cortisol values were obtained at 9 pm.

Table 6. Cortisol levels of the participants at different time points, CAR and CDD

	Mean Cortisol		
	N	nmol/L	SD
At wake up	92	14,5	7,4
One hour after wake up	91	19,7	8,0
Mid day	92	3,7	2,9
9 pm.	92	1,4	1,9
CAR	91	5,2	10,4
CDD	91	20,1	7,4

Burnout

By calculating the SMBQ scores, the employees were assigned into one of four burnout groups. About 10% of the employees were assigned to the pathologically burned out group and about 14% were assigned to the highly burnt out group.

Significant correlations were seen for the burnout score and ERI ($r = .49, P < .01$), noise annoyance ($r = .35, P < .01$), tinnitus ($r = .24, P < .05$) and sound fatigue ($r = .34, P < .01$). This indicates that burnt out people to a higher extent experienced poor reward for their efforts. They were also more annoyed by the noise, experienced more tinnitus and suffered more from sound fatigue after work.

Fatigue

Fatigue was evaluated by use of the SOFI questionnaire. The mean ratings of the four dimensions used were lack of energy (1.8, SD 0.9), physical discomfort (1.7, SD 0.8), lack of motivation (1.3, SD 0.4) and sleepiness (1.2, SD 0.4). The subscales values were used as a dependent variable in the analyses of associations with work environmental factors. The strongest effect was observed for lack of energy based on the mean score.

Sleep and sleepiness

The sleep quality was assessed using KSS and KSD. The KSS and the KSD ratings were mainly used as dependent variables in the analyses of associations with different work environmental factors. Furthermore, recuperation was assessed with questions regarding how rested the employees were after work, after a night's sleep and after a weekend not working (Figure 12).

As can be seen from Figure 12, the majority of the employees were rather tired after a day at work. About 14% were tired or completely worn out. After a night's sleep 5% reported being fully rested. After a weekend off from work 24% reported being fully rested and 9% still reported being rather tired.

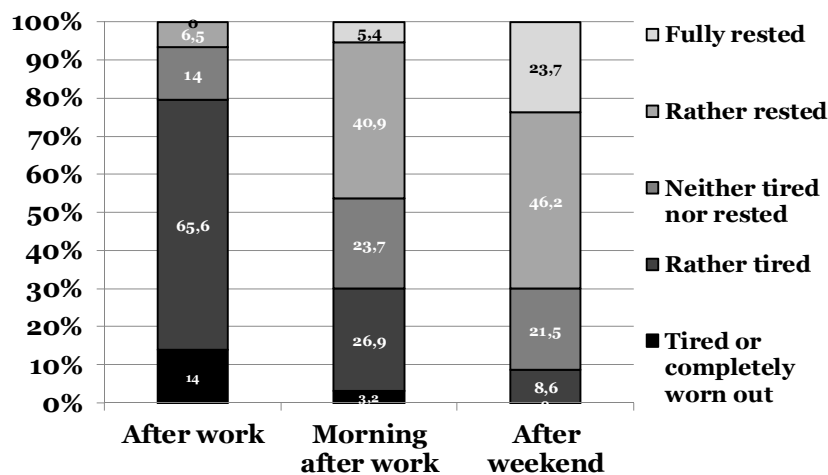


Figure 12. Employees rating of fatigue after work, in the morning after a work day, and after a weekend not working.

Interactions

Noise and effect interactions

Different effects of the sound environment at the preschools were identified. The recorded sound level by use of stationary recordings showed a significant association with ERI ($r = 0.205$, $P < .05$). The higher the sound level the higher the ERI score. A significant correlation was also seen for the mean number of sound events above 85 dB(A) and ERI ($r = 0.273$, $P < .05$). In other words, the more number of sound events above 85 dB(A) the higher ERI score.

Employees reporting working under high stress also had a significant higher exposure of mean number of sound events above 85 dBA compared to low stress employees (72.5 and 59.8, respectively, $t = -2.0$, $df = 76$, $P < .05$). No significant correlations were seen between sound levels recorded by noise dosimeter and any of the outcome variables.

Associations were also seen between outcome variables and the subjective rating of the sound level. The group of employees reporting high sound levels at work also reported the highest ERI ($F(89/91) = 4.91$, $P < .05$). Employees with high burnout scores also reported higher noise levels at work compared to employees with lower burnout ($F(88/91)=2.87$, $P < .05$). The group of employees reporting high sound level at work also reported being more tired before going to bed ($F(89/91) = 3.40$, $P < .05$).

Analyses of the reported sound fluctuation revealed that the group of employees reporting a high sound level fluctuation also had a higher ERI score ($F(88/91) = 2.69$, $P = .05$). A similar association was seen regarding depression ($F(88/91) = 3.23$, $P < .05$). The group reporting high sound fluctuation also had a higher depression score.

Disturbance from the children's voices was also analyzed. Significant group differences were seen between employees rating high disturbance from the children's voices and ERI ($F(90/92) = 4.93$, $P < .05$). High disturbance was associated with high ERI scores. Employees reporting being the most disturbed by noise from the children's activities also reported being more tired before going to sleep ($F(89/91) = 3.40$, $P < .05$).

Similar associations were seen regarding disturbance of noise from the children's activities and ERI ($F(89/91) = 8.39$, $P < .01$), and KSS sleep feelings before going to bed ($F(89/91) = 3.36$, $P < .05$).

A correlation of 0.212 ($P < .05$) was found between the mean number of children present at the department during the week and the cortisol value obtained at work (11:00 am). Thus, more children at the department were associated with higher cortisol values.

As seen from Table 7, sound fatigue was significantly associated with the subjective evaluations of the sound environment in terms of rated sound level, rated sound fluctuations, rated disturbance of the children's voices, rated disturbance of noise from the children's activities and reported sound fatigue after work.

Table 7. Correlations between noise annoyance and subjective ratings of the sound environment and sound fatigue.

	Spearman's		
	N	correlation	P-value
Sound level	92	.448**	.00
Sound fluctuation	93	.431**	.00
Disturbance of the children's voices	92	.479**	.00
Disturbance of noise from the children's activities	93	.466**	.00
Sound fatigue	92	.285**	.01

Noise and stressors at work

Different stressors at work were rated by the employees (Figure 13). The stressors were associated with the organization of the work (black bars), noise (greyish bars), activities and situations together with the children (black dotted bars) and the child group and its constitution (dashed bars).

The highest rated stressor was experiencing that a child in the group needed special support, without having extra resources allocated. Conflicts among the personnel and children competing for attention were also rated as high stressors. The highest rated stressors regarding noise were the children's voices and noise when changing the children's clothes. The most stressful work situation was when the children were allowed to play freely indoors, and the least stressful work situation was when the children were engaged in planned outdoor activities.

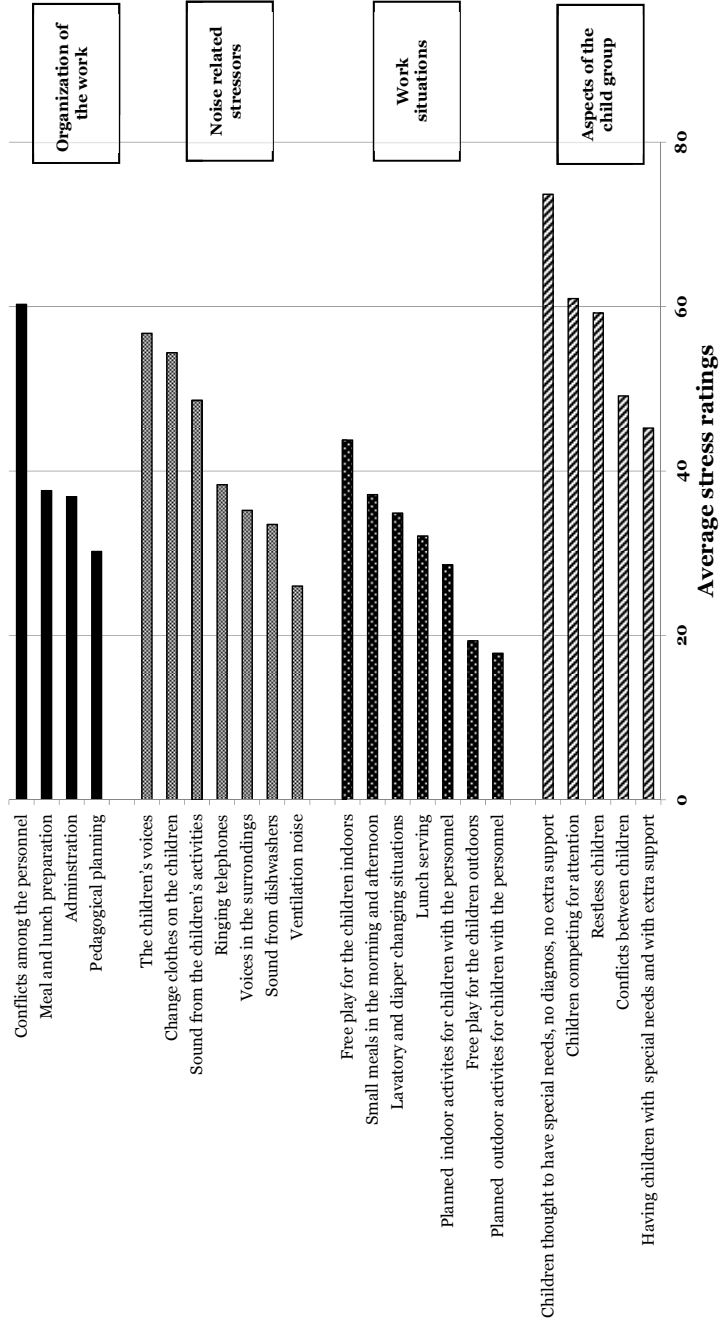
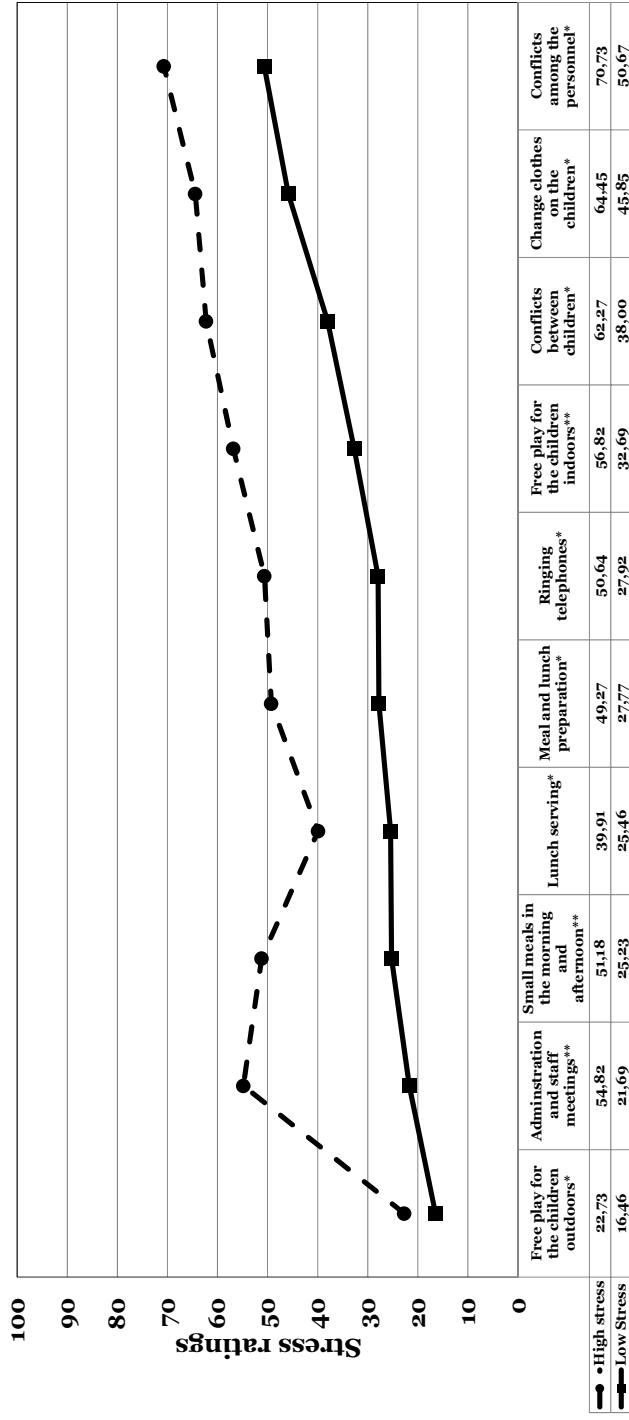


Figure 13. Ratings of experienced stress for different types of stressors separated by different categorization/aspects of the work. Ratings were made on a visual analogue scale ranging from 0 mm (not stressful) to 100 mm (almost unbearable stressful).

By use of the Stress-Energy questionnaire the employees were dichotomized into two groups (high stress at work and low stress at work). The high stress group in general rated all stressors higher than the low stress group. In Figure 14, the significant differences between the two stress groups are illustrated. The significant differences regarding the stressors were mostly seen for the organization of the work and work situations. However, significant differences were also seen for stressors regarding noise and aspects of the child group.



*.P < .05, **.P < .01

Figure 14. Significant group differences between the high and low stress group for different stressors at work

Measures

Objective sound recordings

In Table 8, differences of the sound levels before and after the introduction of the measures are presented. Missing data, regarding number of sound events above 85 dBA, in Table 8, is due to technical limitations for some of the used noise dosimeters.

Analyses revealed significant changes comparing the stationary noise levels in two preschools with acoustical measures, Sound absorbing tables ($t(4) = 9.16, P < .01$) and new toys ($t(5) = 77.34, P < .01$). In three preschools with organizational measures significant differences were seen for preschools with a new recovery room for the personnel ($t(3) = -.184, P < .01$), recovery room for the children ($t(3) = 26.15, P < .01$) and risk and noise education ($t(5) = 3.33, P < .05$). No significant changes were seen in the three control preschools.

A significant increase in the sound level was also observed, by use of personnel carried noise dosimeter recordings, at the preschool with the new lighting system ($t(5) = -3.18, P < .05$).

Table 8. Changes of physical measurements after the introduction of the different preventive measures

	N	dB(A)Leq dosimeter recording	P	dB(A)Leq stationary recording	P	Sound events above 85 dB(A)	P
New ventilation	5	0.38	.74	-0.38	.89		
Sound absorbing tables	4	-0.71	.33	-1.18	.01		
Noise isolation wall panels	6	-0.57	.57	2.54	.10		
New toys	6	-0.91	.48	-2.51	.00		
Less children	8	-0.20	.65	-0.12	.82	7.97	.63
New play hall	4	-0.35	.55	-3.13	.25	-10.05	.28
Acoustical measures	33	-0.39	.25	-0.60	.33	10.87	.41
Voice education for the personnel	5	-0.79	.30	2.12	.06	24.49	
Noise pedagogics for the children	3	-0.45	.76	-1.42	.23		
Recovery room for the personnel	4	0.15	.87	-1.96	.00	-94.42	.52
Recovery room for the children	4	0.70	.44	-0.52	.00	-45.15	.06
Regulation of the light	6	2.21	.03	1.03	.11	7.81	.49
Risk and noise education	5	0.05	.95	-0.89	.02	-8.75	.67
SoundEar	4	-0.41	.25	-0.07	.94		
Organizational measures	31	0.32	.32	-0.24	.67	-22.66	.26
Control schools	14	-0.07	.87	-0.72	.23	.05	1.00

Subjective evaluations of the sound environment

Differences were observed in the ratings after the implementation of both acoustical and organizational measures preventive measures in preschools (Table 9).

The preschools with a reduced number of children reported a significant improvement regarding disturbance from the children's voices ($z = -2.00$, $P < .05$, $r = -0.45$). At the preschool with noise isolation wall panels a close to significant improvement was seen regarding the rated sound fluctuation ($z = -1.84$, $P = .07$, $r = -0.53$). Similar results were also seen for the preschool with the new toys concerning rated sound fluctuation ($z = -1.84$, $P = .07$, $r = -0.53$).

The preschools with organizational measures reported no significant improvements regarding the subjective evaluation of the sound environment. However, the preschool with "voice education" reported a significant increase in noise annoyance after the implementation of the measure ($z = -2.02$, $P < .05$, $r = -0.64$).

No significant differences were seen for the control preschool regarding the subjective evaluation of the sound environment, except for a reported increase in disturbance of noise from the children's activities ($z = -2.12$, $P < .05$, $r = -0.40$).

When analyzing differences before and after the introduction of the preventive measures group wise (acoustical and organizational measures), the preschools with acoustical measures reported a significant improvement regarding rated noise fluctuation ($z = -2.39$, $P < .05$, $r = -0.29$).

Table 9. Changes in ratings of the subjective evaluation of the sound environment after the introduction of the different measures

		Sound		Sound		Disturbance of		Disturbance of		Noise		Sound	
	N	level	P	fluctuation	P	children's voices	P	noise from children's activities	P	annoyance	P	fatigue	P
New ventilation	5	-0.17	0.66	-0.17	0.56	0.00	1.00	-0.17	0.32	6.00	0.28	0.33	0.58
Sound absorbing tables	4	0.40	0.16	0.20	0.79	0.00	1.00	0.00	1.00	1.60	1.00	0.25	0.37
Noise isolation wall panels	6	-0.17	0.71	-1.33	0.07	-0.17	0.32	-0.17	0.32	-9.17	0.07	-0.33	0.32
New toys	6	-0.17	0.71	-1.60	0.07	0.17	0.32	-0.17	0.35	-11.00	0.35	0.17	0.32
Less children	8	-0.63	0.13	-0.29	0.48	-0.50	0.05	0.00	1.00	-5.75	0.40	-0.50	0.23
New play hall	4	0.25	0.32	-0.25	0.32	0.00	1.00	0.25	0.32	-6.25	0.29	-0.25	0.66
Acoustical measures	33	-0.14	0.34	-0.58	0.02	-0.12	0.21	-0.17	0.41	-4.03	0.12	-0.09	0.54
Voice education for the personnel	5	0.40	0.16	-0.20	0.56	0.00	1.00	-0.25	0.71	13.40	0.04	0.20	0.32
Noise pedagogics for the children	3	0.25	0.32	0.25	0.32	-0.25	0.32	0.25	0.32	-1.00	1.00	0.50	0.41
Recovery room for the personnel	4	-0.25	0.56	0.25	0.56	0.00	1.00	0.00	1.00	-11.00	0.29	0.00	1.00
Recovery room for the children	4	0.50	0.16	0.25	0.66	0.00	1.00	-0.25	0.32	-7.50	0.47	0.50	0.66
Regulation of the light	6	-0.17	0.32	0.17	0.56	0.17	0.32	0.00	1.00	-1.17	0.75	0.33	0.48
Risk and noise education	5	0.00	1.00	-0.40	0.32	0.20	0.32	0.20	0.32	-0.20	0.72	0.00	0.41
SoundEar	4	0.00	1.00	0.00	1.00	0.40	0.16	0.00	1.00	-7.80	0.47	-0.50	0.16
Organizational measures	31	0.09	0.37	0.03	0.83	0.09	0.18	0.00	1.00	-1.76	0.50	0.22	0.25
Control schools	14	0.00	1.00	-0.23	0.43	0.00	1.00	0.43	0.03	-0.36	0.42	0.00	1.00

Discussion

Noise exposure

The sound levels measured both from the personnel carried noise dosimeters and the stationary microphones were surprisingly homogeneous comparing the departments. On average the equivalent sound level was 64 dB(A) in the dining rooms. A similar sound level was seen for the play halls. The average equivalent sound level for personnel carried sound measurements was 71 dB(A). The stationary sound levels in the dining rooms and the play halls were on average 5 – 10 dB lower than the personal exposure levels. The difference in sound level between the stationary measurements and the personnel carried noise dosimeter measurements is most likely explained by the different activities throughout the work in the preschool. The stationary microphones in the dining rooms do not fully capture all the activities ongoing in the different rooms, or the noise levels outdoors. Furthermore, the dining rooms and play halls were also used for different activities during the day such as playing, eating or other types of activities. The personnel carried noise dosimeter microphones are also most likely closer to the noise source (the children). The personnel recording more pronouncedly capture the noise levels generated from crying, shouts and otherwise noisy activities of the children. The higher noise levels measured by the personnel carried noise dosimeter may also be explained, to some extent by the speaker's own voice. However, the speech contribution is expected to be low (about 2dB(A)) according to the microphone position study carried out (66).

The difference in equivalent sound levels at the departments was also small when comparing the days of the week. The small difference is most likely a result of the uniformity of the activities made each work day. Activities such as the arrival of the children, eating situations, rest periods and different indoors and outdoors activities are often carried out at the same time every day. However, the noise exposure varies a lot over the day being highly dependent on the different activities carried out during the day. Besides, the variations in noise levels were correlated with the varying number of children present at the department. Time periods corresponding to eating and activities in the afternoon with many children present indoors is highly reflected in the mean number of sound events above 85 dB(A) per hour.

Focusing on the daily exposure of the employees by use of the noise dosimeter recordings showed that the individual exposure varied between 60 to 85 dB(A). Only one individual noise exposure exceeded the limit of 85 dB(A), a limit set to minimize the risk of developing a noise induced hearing

loss (91). For most of the employees the noise exposure was well below this risk level.

An important aspect of the exposure is the fluctuation of the noise, verified by the personnel carried noise dosimeter recordings. As expected, the time periods of high fluctuation derived from periods with many children present at the department and also from their voices and the ongoing activities. Other noise sources contributing to the mean number of sound events above 85 dB(A) were ringing telephones, footsteps and doors closing, etc. The subjective experiences of the noise fluctuation were in agreement with the measured mean number of sound events.

The frequency of the noise is also of interest when evaluating the sound environment at the preschool. Although no frequency analyses were made in this thesis, the noise, which was dominated by voices, should mainly contain frequencies in the mid and high frequency range. The dominating mid and high frequency range is further verified by the relatively low difference between the dB(C) and the dB(A) levels.

As expected the sound levels at the departments were correlated with the number of children present. Significant correlations were seen for both the stationary and the personnel measurements. An increase in number of children was associated with an increase in the sound levels and the mean number sound events above 85 dB(A). The recorded changes of the sound levels related to the number of children, however, were rather small. An explanation of this weak correlation is the way in which the number of noise sources affects an equivalent sound level. If all children are assumed to contribute with an equal sound level, a reduction of half the children or a doubling of the number of children would correspond to an decrease or increase in the equivalent sound level by only 3 dB(A). However, the noise level generated by each child is most likely also affected by social interactions and individual behavioral aspects of the children. In paper III, the measurements from data collection 1 and 2 in study 1 were analyzed. A reduction of half of the children resulted in an equivalent sound level reduction close to 4 dB. The additional effect is most likely explained by that the children become louder when participating in a larger group, which is a result of the Lombard effect (92).

A further possible explanation of the weak correlation between the sound level and number of children present at the departments is that the personnel work in close contact with the children regardless of the number children present at the department. With many children present, the children are often divided into smaller work groups with only one teacher

responsible for each work group. With few children present at the department, the teachers may not always divide the child group into smaller work groups, but instead all work together. By doing so the noise exposure from the children remains equal.

Subjective responses to the noise exposure

Noise was rated as the most troublesome environmental factor. The most disturbing noises came from the children's voices and noise from their activities. Children playing freely indoors and eating situations were rated as the most stressful noise situations. In the observation study, (paper IV, study 2), a high number of contacts between the employees and the children was observed, verifying the high ratings of the disturbing effects from the children's voices. Furthermore, the employees with high stress also rated eating situations as more stressful than employees with low stress.

Having the children engaged in outdoor activities was rated low concerning experienced stress. The findings strengthen the conclusion that the numerous close and immediate contacts with the children's voices indoors is a high stressor for the employees. This conclusion is further strengthened by the high stress ratings in situations when changing the children's clothes.

Considering the reported situational related disturbances, the number of children present at the departments become of special interest. The responsibility for several children in these troublesome situations may contribute to acute stress. The perceived stress of the employees during different situations may not only be dependent on the noise generated by the children but also on the high work load. Most likely, the perceived stress is a combination of several different stressors. However, the noise exposure in the preschool is most likely a major component in the development of acute as well as long term stress in the preschools.

Effects of the noise exposure

When evaluating the effects on health by use of either personnel carried noise dosimeters, stationary measurements or subjective evaluations of the sound environment, the subjective evaluations were the most relevant indicator in the impairments of the work and health status.

A reduction in hearing thresholds was seen for many of the employees, for all screened frequencies. The highest prevalence of reduced hearing thresholds was seen for the frequencies 6000 Hz and 8000 Hz. The analyses revealed a correlation between noise exposure and the audiometric frequencies

between 250 Hz and 2000 Hz. However, when applying the standardized national evaluation of hearing loss on the audiometric screening (89), no employees reached the criteria of a having a hearing loss. The reductions in hearing thresholds found are still surprising considering the fact that the noise exposures are well below the established occupational limit. Other factors beside the equivalent sound level are likely to affect the hearing thresholds of the employees, not at least responses related to the experiences of the complex noise environment in combination to characteristics and efforts of the pedagogic work carried out.

A further indication of the impact on health from the sound environment was the high prevalence of tinnitus at 31%, compared to 20% in the average population (36-38). No associations between experienced tinnitus and the noise exposure, however, were identified. In a separate analysis (93) the results, however, indicated an association between tinnitus and stress related health. Impaired hearing, subjectively reported, was associated to an increased prevalence of tinnitus. The results indicate an association between tinnitus and experienced hearing status, as well as fatigue and a worry about the poor acoustic environment.

A further strong indication of the poor acoustic environment is the high prevalence of sound fatigue. A majority of the employees reported sound fatigue several days or more per week after work. The sound fatigue was not explained by the measured noise exposure, but an association was found between noise annoyance and disturbance from the children's voices and activities. An association was also found between number of sound events above 85 dB(A) and rated stress at work.

Among the stressful situations at work, eating situations with the children was clearly identified. Data from the observations study revealed a high number of contacts with the children in these situations. Since speech and listening are of high importance in the daily work, the experienced noise annoyance is probably an effect of the noise levels from the children's voices. Furthermore, the frequencies of the children's voices are in the range of the highest hearing sensibility, which in turn also may be added to the experienced noise annoyance. With the children's voices being the dominating noise source, the masking effect of relevant speech can also be assumed to be pronounced in combination with high sound levels and a high degree of sound fluctuation. The masking effects are in strong conflict with the need for concentration contributing to higher stress and fatigue.

About half of the employees reported working under high stress using the stress-energy model. This result is in accordance with previous research

showing that preschool teachers and child care workers are exposed to a high work load and work with high stress (51). Interestingly, all employees also reported working with a high commitment and energy at work. The pattern regarding stress – energy, at work, is rather unusual compared to other studies (94), both regarding the high commitment of all employees, as well as the fact that no employees were characterized as worn out or bored. The results of the ERI questionnaire further strengthen the conclusion that the work with children is highly rewarding, despite the poor acoustical environment and experienced stress.

The group of employees working under high stress (study 2, paper IV) also differed regarding CAR and CDD. The employees with high stress had a higher CAR compared to the low stress employees and also a lower CDD. These results, even though not significant, are in line with previous research (95) showing that daily stress is associated to higher cortisol levels increase in the morning. Exhausted individuals were also shown to have a lower cortisol variability over the day (96). Our cortisol data also showed an association between the first cortisol value (at wake up) and rated noise annoyance. A high morning cortisol value was associated with high noise annoyance, thus resulting in a lower CAR. This result is not in line with the finding of a high CAR for employees reporting high stress, since employees with high stress also reported higher noise annoyance. Also other recent research has shown inconclusive results regarding cortisol data and the interpretation of cortisol data should therefore be made with caution (97).

As expected, the employees with high stress levels generally rated the different stressors in the preschool as higher compared to low stress employees. However, some stressor differ significantly between the low stress and the high stress employees showing that different aspects of work are perceived differently depending on the experienced stress.

A severe consequence of long term stress may be a development of burnout syndromes. The prevalence of highly or pathologically burnt out employees in paper II was 25%. The ERI model was correlated to burnout, indicating that even though the reward was rated as high, it did not balance the high effort required. Thus, a low job satisfaction may be associated with burnout and vice versa. In general, the employees with a high burnout also rated the acoustical environment as poorer and reported higher stress levels. The results indicate that employees with a high reported burnout also show a higher sensitivity and a lower coping ability to noise.

Depression was assessed in paper II (study 1). The data showed that no employee suffered from a major depression. The lack of depression may be

explained by a healthy worker effect. That is, employees suffering from a major depression are most likely unable to work. Furthermore, it is also likely that the high commitment and engagement in the preschool work as a counterweight toward depression.

The evaluations of fatigue also support the conclusion that the employees in the preschools are highly motivated at work as was shown by the energy ratings. Low scores were seen for the subscales energy, physical discomfort, lack of motivation and sleepiness at work. The risk of developing severe long term illness may be increased due to high work load with high levels of fatigue. The study indicated rather low levels of fatigue and no associations between fatigue and noise. An indication of the impact of the sound environment could be seen on sleepiness using the KSS scale. Employees being more disturbed by noise from the children's activities were more tired before going to sleep. The same correlation was seen for the rated sound level and tiredness before going to sleep.

Stress and high work load are not always hazardous for the employees as long as the individual is given the possibility to recuperate. An important factor for recovery is sleep quality. Previous research has shown an association between burnout and sleep disturbances (15). Furthermore, in paper IV it was also shown that women were more affected by sleep disturbances than men. This gender difference has also been verified in other studies (98). However, in the present thesis (studies 1 and 2) no associations were seen between poor recovery in terms of sleep quality or sleepiness in the morning and health in terms of stress and burnout.

The correlations between subjective ratings of the sound environment, health and well-being might partly be attributed to the result of a general negative affectivity. However, since correlations were also found with objective sound characteristics this cannot provide a full explanation.

Somewhat unexpectedly, no correlations were found between noise annoyance and sound level or fluctuations. One reason for the absence of such correlations may be that sound level and fluctuations were not the critical aspect of the exposure, which is not unlikely when speech is the most annoying noise source. One conclusion would be that the experienced stress and burnout are influenced by the complex sound environment at the departments. The conclusion is supported by the report of the employees. The noise exposure measurements also support this conclusion, however, the results were not significant.

Noise and other stressors

Noise may, aside from the effect on rated health, also have an impact on the actual work situation. When comparing different noisy situations with other stressors, noise was rated among the highest along with conflicts among the personnel or having children with special needs in the child group. In contrast to the stressor conflicts among the personnel and children with special needs, noise is a constant ongoing stressor, which may augment the effect of other stressors.

The high stress ratings of different daily work such as eating situations are most likely a combination of high work load and a noisy environment. This is especially so when combined with high needs for communication and care taking of the children. It is difficult to clarify the role of the noise for the high stress ratings in these situations.

The organization of the work is most likely also important for the experienced stress and work load as the noise. Considering that only one-third of the employees felt that they were able to do the job they were supposed to do, and about 80% reporting not being able to give the children the attention and time they needed, the organization of the work is of special interest. Furthermore, a majority of the employees also reported having several different work tasks, and about 30% found this stressful to a high degree.

The results in paper IV (study 2) suggest that a good leadership with a well-planned work organization is of importance for the reduction of the experienced stress.

Measures

By introducing acoustical and organizational measures changes were observed in the sound level at the departments. Most pronounced changes, regarding acoustical measures, were seen for departments with sound dampened tables and new toys. The lower sound levels are most likely an effect of the reduction of transients in the sound and generally lower sound generation from the children's activities. About the organizational measures, improvements were seen for the recovery room for the personnel, the recovery room for the children and noise education. The benefit of well rested employees may have an influence in the daily work such as in having the energy to improve the work situation and changing the organization of the work. The benefit of good opportunities for the children to recuperate may result in less crying and less conflicts among the children. The noise and

risk education may have influenced the employees to organize the work in a different way and to have a more active approach in improving the sound environments. However, this was not controlled for in the study.

The improvements of the sound environment were more pronounced in the subjective ratings than the objectively recorded sound levels. Noteworthy is that the changes in the sound environment were in general, small and in most cases not significant.

Due to low power in the statistical analyses of the different measures, the conclusions regarding improvements should be made with care. However, using a wider perspective when interpreting the data, in general the changes in the measured sound levels using both personnel and stationary measurements and mean number of sound events above 85 dB(A), changes were seen in a positive direction. For 11 of the 14 (79%) of the analyzed effects on the sound environment a positive change was seen regarding acoustical measures. For the organizational measures improvements were seen for 11 of the 19 (58%) variables. This may indicate that the acoustical measures to a higher extent improved the sound environment compared to the organizational measures.

Using the same perspective, interpreting the changes regarding subjective evaluations of changes in the sound environment, the employees with acoustical measures rated an improvement for experienced noise levels, sound fluctuations, disturbance from the children's voices and activities, noise annoyance and sound fatigue in 21 of the 36 (58%) of the rated outcomes. For the organizational measures the corresponding result was an improvement in 13 of 36 (36%) of the rated values.

An explanation for the poorer outcome of the organizational measures is probably the longer implementation time needed for improvements. Changing the ways of work or undergoing an education program is a time consuming process and its effect on the sound environment is not always immediately noticed. The organizational measures are also highly dependent on the fully committed employees who are already working with a high work load. The acoustical measures require less effort from the employees and the effects are normally more instant.

The changes observed both regarding stationary and personnel measurements were small. This was also true for the subjective evaluations of changes of the sound environment. However, small changes in the sound level may have a substantial impact on the estimated health hazards. Reductions of 3 dB in the equivalent sound level make it possible to double

the exposure time and a reduction of 1.5 dB increases the possible exposure time with 50%. In the present study the reduction of the equivalent sound level varied between 0.05 to 2.5 dB. It is likely that the reduction in some cases has a positive impact on reducing the hazardous effect of the noise. Most likely the effects of the different measures, however, are seen in terms of improving the sound quality. Combinations of different measures are likely to improve both the sound level and the sound quality.

Limits and further research

The present thesis should be considered in the perspective of the limited number of subjects participating. Besides, the thesis mainly focuses on the work related stress factors reported and described by the personnel. The effect and contribution of stressors outside work are not included in the study. A specific weakness of the thesis is the rather small number of observations for each evaluated measure. As a result the statistical power will be low. The use of more preschools, departments and employees were discussed when designing the study. Increasing the power of the study, however, was in conflict with time needed for such a study. Increasing the study group by two, three or four times were considered to be in conflict with making repeated measures over 3 to 5 years. The loss of subjects and the risk for irrelevant changes over time were considered to lower the reliability of the study. The analyses using the employees as their own controls were considered of great importance, as well as to limit the time period of the study. A combination of several measures would most likely have resulted in a better impact on the work environment. Future studies are suggested to include several acoustical measures combined by deeper control of the non-work related variables that might interact with the noise induced effects.

Conclusions

The noise exposure of the employees in the preschool is influenced by a number of complex and interacting sound parameters. The influences of the variability of the noise exposure on health are of special importance, especially when considering the overrepresentation of reduced hearing thresholds, tinnitus and noise annoyance. An essential finding of the thesis is that noise and noise sources may impair the performance of the pedagogic work thereby increasing the work load of employees. It is assumed that noise exposures in the preschool, isolated or in combination with other stressor, play a fundamental role in the building up of acute as well as long term stress. Noise from the children's voices and their activities increased the noise annoyance, masking, work load and thereby burnout and fatigue responses. As a consequence, due to disturbances in the pedagogic work, this indicates a risk for higher stress levels, especially when working in departments with large child groups. The employees who suffer from burnout show a lower capability of coping with stress and workload, but also a higher sensibility to the complex sound environment. The long term and situational effects of the noise are combined with a number of other work related factors. The stress-energy and the fatigue ratings speak for a working situation and employment with a high degree of commitment and motivation. Acoustical measures improved the noise situation as well as the subjectively rated experiences better than the organizational measures. The interactions between noise and other stressors with regard to well-being, stress and ill health, however, should be based on a multidisciplinary approach that include physical as well as behavioral and organizational work related aspects.

A theoretical overview of the work environmental noise and its effects on the experienced noise, stress related health and the work organization are illustrated in Figure 15. It is assumed that the environmental noise affect the individual response in term of experience of the noise, noise annoyance and hearing. The work environmental noise is also assumed to have an effect on stress related health and work organization. The response of the noise is also assumed to be influenced by individual factors such as age, gender, physical and psychological well-being etc. The experiences of noise, stress related health and work organization is, furthermore, also affected by external factors such as living conditions, family constitution, political decisions etc. A relation is also plausible between the experiences of noise and stress related health. Individuals highly sensitive to noise or suffering from hearing impairments may develop stress related ill health to a higher extent. It is also assumed that high levels of stress and burnout are associated with fewer

possibilities in coping with the noise, thus increasing the noise sensitivity. An association between work organization and stress related health is also assumed. Poor organization of the work and lack of leadership may increase the stress levels among the employees.

High stress levels and high burnout may in turn decrease the possibility to improve the conditions at work. By changing the work organization the noise can be affected in a positive way. External factors, not at least political decisions, e.g. lowering the number of children at the departments, fundamentally will have an impact on the work environmental noise situation and thus the health of the employees.

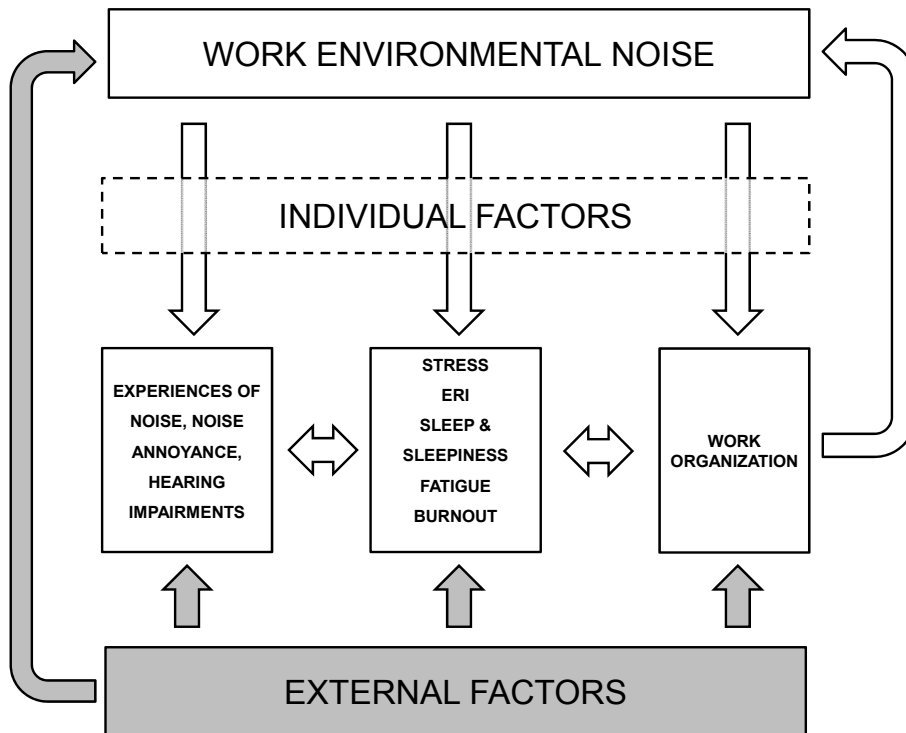


Figure 15. Theoretical overview of work environmental noise and its effect on “experiences”, “stress related health” and “work organization”, influenced by “individual” and “external” factors.

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