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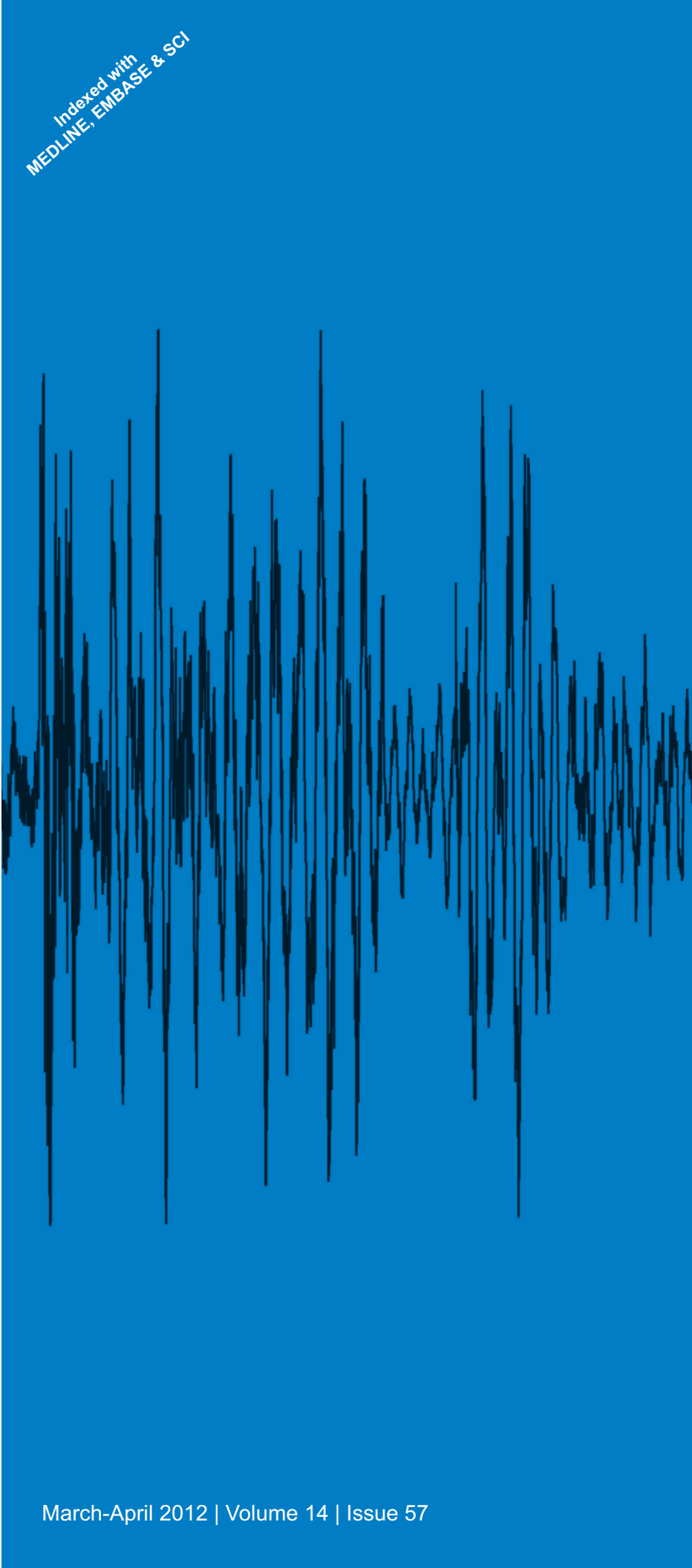
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# Noise exposure and auditory effects on preschool personnel

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## Abstract

Hearing impairments and tinnitus are being reported in an increasing extent from employees in the preschool. The investigation included 101 employees at 17 preschools in Umeå county, Sweden. Individual noise recordings and stationary recordings in dining rooms and play halls were conducted at two departments per preschool. The effects of noise exposures were carried out through audiometric screenings and by use of questionnaires. The average individual noise exposure was close to 71 dB(A), with individual differences but small differences between the preschools. The noise levels in the dining room and playing halls were about 64 dB(A), with small differences between the investigated types of rooms and preschools. The hearing loss of the employees was significantly higher for the frequencies tested when compared with an unexposed control group in Sweden. Symptoms of tinnitus were reported among about 31% of the employees. Annoyance was rated as somewhat to very annoying. The voices of the children were the most annoying noise source. The dB(A) level and fluctuation of the noise exposure were significantly correlated to the number of children per department. The preschool sound environment is complex and our findings indicate that the sound environment is hazardous regarding auditory disorders. The fluctuation of the noise is of special interest for further research.

*Keywords:* Auditory effects, hearing loss, noise fluctuation, noise, preschool, tinnitus

## Introduction

Hearing impairment is a well-recognized risk in many industrial work places, where the noise often reaches levels close to or above 80 dB(A). Pedagogical workplaces such as preschools and elementary schools seldom reach these noise levels, but noise is still regarded as a problem by the personnel.<sup>[1,2]</sup> Further research is needed regarding the relation between exposures and adverse effects in these environments. The noise environment in the preschool differs from traditional industrial workplaces as the noise is generated from a number of isolated and interacting sources. The contribution from children's and staff's voices is a fundamental part, as well as the contribution from activities, e.g. footsteps, doors, furniture, cutlery, toys, dryers and telephones. Besides, the ventilation noise will add a monotonous background exposure. The reported noise exposure levels do not speak for a pronounced risk

for hearing damages. Nevertheless, hearing impairments have been reported to an increasing extent in the preschool environments.<sup>[3]</sup> The search for an explanation to this, besides the noise levels, is of great importance.

Noise exposure in the preschool is characterized by several features that are harmful in the perspective of the pedagogic work that is carried out. Besides the relatively high daily noise level, the environment includes a number of sources making fluctuations a pronounced part of the exposure. In addition, the noise is dominated by voices with frequency and informational characteristics that make the risk for hearing impairment and annoyance highly pronounced. This noise exposure is in conflict with the demands of the work in several aspects, not least the communication part of the education.

The annoyance and the effects on speech and listening at the occurring noise levels have been verified in several studies.<sup>[4]</sup> However, the consequences of long time exposures in preschool environments, characterized by high mental effort and other stressors, are far from clarified. It is a well-grounded assumption that this might be a critical part of noise interactions in the preschool environments.

The adverse effects of sound frequency and noise level fluctuations have been described in a number of previous

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studies. A fluctuating noise and uncontrolled sound is more likely to catch the attention than a constant sound and, therefore, is especially harmful when the demands of concentration are high.<sup>[5]</sup>

Noise exposure not only increases the risk of developing a hearing loss but other hearing impairments such as tinnitus and hyperacusis also constitute possible effects of the exposures in preschools. Tinnitus prevalence in the general population is approximately 10–15%.<sup>[6-8]</sup> It has also been shown that tinnitus is more common among patients with hearing loss.<sup>[9,10]</sup>

Hyperacusis is a hearing disability often seen in conjunction with tinnitus. Hyperacusis is a form of oversensitivity to sounds where the listener experiences the sound as louder and more annoying than the normal listener. The noise leading to such effects can be of a low intensity when considering daily sources.<sup>[11]</sup> Hyperacusis may have severe consequences for daily life, making it difficult to participate in work as well as spare time activities. It has been shown that people suffering from hyperacusis are also more tensed when exposed to high sound levels.<sup>[12]</sup>

A more rare hearing impairment is diplacusis, which is a sensation of changed perception of sound.<sup>[13]</sup> Most common is a sensation of tones that vary regarding pitch when listening with both ears thus called binaural diplacusis.<sup>[14]</sup> More rare is a condition called monaural diplacusis, a condition where a single tone's pitch is perceived as two different sounds in the same ear. Diplacusis is commonly found in patients with cochlear hearing impairments.<sup>[15]</sup>

Working in a noisy environment may lead to sound fatigue.<sup>[16,17]</sup> The effect can be described as a type of oversensitivity to the general surrounding sounds, which affects the sufferer at the end of the work day when leaving the noisy environment. The fatigue sensation often creates a problem in home environments. Subjects suffering of sound fatigue strive to avoid all sound sources regardless of the sound characteristics. This state of noise fatigue usually declines with time if staying in noise-free environments.

Other adverse effects of noise are distraction and annoyance. This means that the noise makes work more demanding to execute with a higher cognitive load and fatigue as a result, especially when the work task relies on auditory information.<sup>[5]</sup> The more working hours in a noisy environment, the larger the mental fatigue.

The masking effect of noise raises the cognitive load most often as an effect making speech communication more difficult<sup>[4]</sup> and thus contributing to the cognitive fatigue. The masking effect is also important regarding safety issues, as important information or alarms might be missed. Working in noisy environments may also have a negative impact on

the speakers voice, especially among women.<sup>[18]</sup> Masking may lead to vocal problems, especially in pedagogical environments, with the voice being an important tool for the teacher.<sup>[19]</sup> The correlation between noise exposure and overall ill health in preschool environments however is far from clearly described.

## Aims

The aim of this study was to clarify the noise exposure for the preschool personnel. Within the noise assessment, a focus was the specific noise sources and their characteristics, especially the sound level variability.

Another aim of the study was to describe the prevalence of different auditory disorders and adverse effects: hearing impairment, tinnitus, hyperacusis, sound fatigue, masking, voice effects and annoyance. In this study, we also analyzed to what extent the exposure could predict and explain the subjective and objective measurement of different auditory disorders.

## Methods

### Participants

An invitation to participate in the study was administrated by the local authorities to the principles of all regional municipal preschools ( $n = 64$ ). In meetings with the principle and representatives from each department at the preschools, two departments at each preschool were selected. Because follow-up measurements were planned after measures had been taken to lower the exposure levels, schools were excluded if there were any planned staffed changes during the research period. For the same reason, departments that had plans for renovation or other physical changes at the department were also excluded.

In each department, three subjects were offered to participate in the study. The selection criteria regarding participants were based on the employment status and working hours. Personnel with a position of at least 30 work hours per week were included in the study. All participating personnel were employed as preschool teachers or childcare workers. The selection criteria resulted in the selection of 87 females with a mean age of 41.5 years (SD 10.0 years) and 14 males with a mean age of 38.7 years (SD 10.5 years). A total of 101 subjects were included in the study with a mean age of 41.0 years (SD 10.0 years).

### Reference population

To evaluate changes in hearing thresholds among the employees, comparisons were made with a Swedish reference population of Johansson *et al.*<sup>[20]</sup> A control group was established with matched age as the study group. In the comparisons, the hearing threshold of the 50<sup>th</sup> percentile was used.

## Character of the work

The work of the employees was highly dependent on the time schedule and the presence and activities of the children. The character of the work and periods of activities of the investigated preschools were found to be uniform. The children arrived to the schools between 08:00 and 10:00 am. The employees served the children an early morning meal between 09:00 and 10:00 am. During a period between 10:00 and 11:00 am, the children were engaged in different activities inside or outside the departments. Lunch was served between 11:00 and 12:00 am, after which the youngest children (1–2 years) slept for 1–2 hours. The older children had a rest time for about 1 h with a low-intensity activity. The period between 01:00 and 02:00 pm was characterized by playing, reading and other different types of indoors or outdoors education. At 02:00 pm, a small meal was served and the previous tasks were continued after finishing the meal. The children were leaving the preschool between 03:00 and 05:00 pm, including contacts between the parents and the employees.

## Data collection

### *Presence of children*

The preschool personnel kept records of the children's attendance during the working day. The data regarding number of children present each day, the children's age and gender were collected at the end of the study week by the research group.

## Department characteristics

Observations of the premises, the size of the different rooms, number of windows and doors and the construction of the preschool and the participating departments were made by the study group and noted in a standardized form.

## Exposure measurement

### *Personal carried sound recordings*

Two types of noise dosimeters were used, Brüel and Kjaer 4445 and Larson Davies 706-Atex. The noise dosimeters were calibrated each week using the Brüel and Kjaer Sound Calibrator – Type 4231. The Larson Davies 706-Atex dosimeter was set to log equivalent dB(A), Max dB(A) and peak value dB(C) each second. Because of instrumental limitations (limited memory capacity), the logging time of the Brüel and Kjaer instrument was set on a minute basis. All measurements were carried out with Fast setting of the release time.

All personnel were thoroughly instructed during the first morning (Monday) of the study week on how to mount and handle the individual technical equipment. The participants were informed to start the sound measurement at the beginning of the work day and finish the measurement at the end of the working day. The recordings were carried out from Monday to Friday.

To minimize the risk of the workers own speech to affect the recorded sound level, a laboratory test was conducted. Three positions of the microphone were tested; mounted on the back of the head, above the ear and on the shoulder 5–10 cm from the neck. With a background noise of 70 dB(A), the placement on the back of the head gave an addition of less than 2 dB(A) to the noise while the microphone wearer was speaking.<sup>[21]</sup> A placement of the microphone on the back of the person's head, using a headband, was therefore used in this study.

The participating personnel took notes each workday on whether the children had been inside or outside the preschool, type of activities and an estimate of the number of children in contact with them at each working hour. In this diary, the personnel also noted whether they experienced any technical noise recording difficulties or other incidents that may have occurred during the working day.

### *Stationary sound recordings*

Stationary sound level measurements were collected using two Brüel and Kjaer 2260 investigators with external microphones, one at each department during the study week. The 2260 investigators were calibrated each week using a Brüel and Kjaer sound calibrator Type 4231.

The microphones were mounted at a 2 m height, centered in the room. Two rooms at each department, a dining room and a play hall, were measured during the week. Measurement of one room was conducted from Monday to Wednesday. A second room was measured during Thursday and Friday. The timers were set to measure from 09:00 am to 09:00 pm during Monday and 06:00 am to 06:00 pm during Tuesday to Friday. Because of technical problems, some measurements were not fully completed. The following variables were logged each minute: equivalent dB(A), dB(C) peak, dB(A)max and dB(A)min. All measurements were carried out with Fast setting of the release time. The instruments range was set to 40–120 dB(A), with 1/3 octave bandwidth and peak data up to 135 dB(A).

For each working day, the personnel took notes on ongoing activities in the dining room and the play hall. The data collected included the average number of children in the room per hour and type of activity that had been going on each hour.

## Evaluations of fluctuations of the noise level

The presence of fluctuations of the noise levels was analyzed in the following way. The Larson Davies 706-Atex noise dosimeters logged the highest dB(A) value each second thus giving 3600 peak values per measured hour. In the analysis, we used the number of logged values above 85 dB(A) as an indicator of a sound event that clearly differed from the average noise level. Measured hours that were less than 60 min were extrapolated to a full hour, using the number of logged values above 85 dB(A) and the actual measured time.



## Questionnaires

Several questionnaires were completed by the participants. One of the questionnaires included age, gender, years in occupation and working position, different aspects of the working environment, noise sources, masking effects, personal health and leisure activities.

The work environment was assessed with items regarding prevalence of different work stressors such as lighting, noise, indoor climate, ergonomics and air quality. These questions were followed-up by eight items regarding systematic work place promotion.

Personal health data was questioned regarding medical use, headache, chest pressure, shoulder problems, etc. These items covered the last 30 days. Both spare time and work time prevalence were assessed.

Hearing impairment was assessed using a questionnaire ranging from no problems to strongly impaired. Participants with hearing impairment were instructed to answer further questions regarding the use of hearing aids, discomfort and attention in noisy environments, etc.

Tinnitus was assessed using questions covering the prevalence of tinnitus and how the tinnitus was perceived (both ears, left ear, right ear, other experiences). Questions regarding when and how often tinnitus was perceived were asked together with questions regarding discomfort.

Sound distortion was assessed in a similar way as tinnitus, with questions regarding prevalence and degree of discomfort.

Hyperacusis was assessed using a main question regarding prevalence and degree of discomfort. Furthermore, the participants were given statements of different sound situations. They were asked to answer to what degree they found these situations interfering with hyperacusis.

Sound fatigue was assessed in a similar way as hyperacusis. However, sound fatigue was also rated to what extent it might have a negative impact on leisure time.

Noise annoyance and disturbance were assessed with questions validated from previous studies focusing on the schools' working environments and noise.<sup>[22,23]</sup> A visual analogue scale was used to assess annoyance [Figure 1]. The scale ranged from not disturbing (0 mm) to almost unbearable (100 mm), with five anchor points. The participants were instructed to mark their answer anywhere on the scale.

## Audiometric testing

All participating personnel were tested in audiometric screenings before the study. No audiometric test was older

than 2 years before entering the study. The audiometric tests were conducted in a quiet isolated room at the preschools by a company healthcare nurse. The screening was conducted on both ears with either 0 dB(A) HL or 10 dB HL at 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 3000 Hz, 4000 Hz, 6000 Hz and 8000 Hz, using earphones. A result showing a deviation between ears or a hearing threshold change larger than 10 dB or a decline from previous screening resulted in a referral to an audiometric clinic for further testing.

The employees hearing thresholds were classified according to the Swedish hearing impairment classification.<sup>[24]</sup> The lowest hearing level that is classified as a hearing damage is defined as a mean threshold larger than 35 dB HL for the frequencies 2000 Hz and 3000 Hz. Furthermore, the mean threshold for the frequencies 4000 Hz and 6000 Hz shall exceed 45 dB HL.<sup>[24]</sup>

## Ethics

The study was approved by the regional ethical review board. Each participant was thoroughly briefed about the purpose of the study and how the study was designed. All personnel were informed that presented data would be anonymous and that data would only be presented group wise. All participants gave their written consent to participate. They were also informed that their participation was strictly voluntarily and that they, at any time, could choose to leave the study.

## Results

### Number of children

The investigated preschools were usually open between 06:00 am and 6:00 pm. Most parents left their children between 08:00 am and 09:00 am and fetched them between 03:00 pm and 5:00 pm. The average number of children during the visiting period is described in Figure 2. The mean number of children present during the different days of the week is described in Table 1. On an average, 19 children were registered at the department, and about 14 children attended

**Table 1: Number of children present in the preschools during the different days of the week**

	Minimum	Maximum	Mean	SD
Monday	8	22	13.8	3.2
Tuesday	8	20	14.4	3.3
Wednesday	9	20	14.5	2.8
Thursday	4	22	13.9	3.6
Friday	4	19	11.3	3.7



**Figure 1: Annoyance rating scale applied in the study**

the preschool in average, meaning that approximately 26% of the children were absent each day.

### Experiences of noise

The personnel's experiences of noise, ergonomics, temperature, air and lights were rated on a 1–4 scale. As seen from Table 2, the personnel rated the noise as most annoying of all environmental factors. The differences between noise and other environmental factors were significant to all other environmental factors using one sample T-test ( $P < 0.001$ ).

The personnel's ratings of noise sources dominating the environment at the preschools are shown in Table 3. According to this overview, the noise exposure was dominated by the children's voices and activities of the children.

### Personal noise recordings

Mean values of the mean and max noise levels during the different days of the week are described in Table 4. As seen from the table, the mean noise levels were approximately the same throughout the week. The sound level of the different days of the week was equal to the mean sound level of the week, analyzed using one-way ANOVA ( $P > 0.05$ ).

An overview of the average noise levels exposed to the personnel at each preschool is given in Figure 3. According to the figure, the average equivalent values at the participating preschools varied between 68 dB (A) and 73 dB(A). The

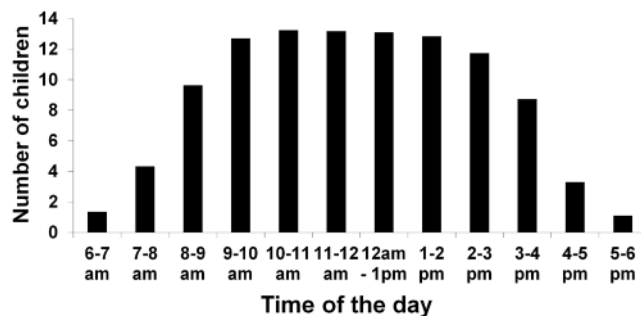


Figure 2: Average number of children present at the investigated preschools during the different hours of the working day

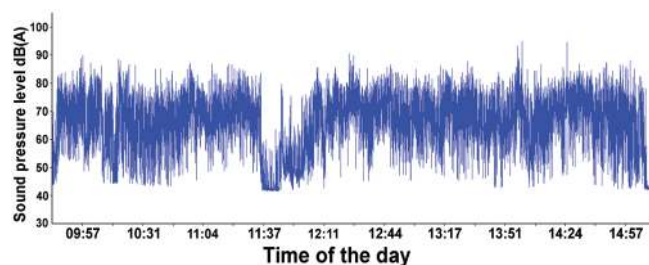


Figure 4: Overview of the levels of fluctuations during an individual noise exposure (1-s logging. Fast release time)

individual equivalent values varied between 60 dB(A) and 85 dB(A).

### Stationary noise recordings

The average values of dB(A) and dB(A)Max in the investigated dining rooms and play halls are described in Table 5. No significant differences were seen between days of the week or between dining rooms and play halls ( $P < 0.05$ ). No differences were seen between any of the investigated preschools.

As seen from Tables 4 and 5, the noise levels in the dining rooms and play halls were lower than the individual doses by approximately 6 dB(A).

### Temporal characteristics

The noise levels varied a lot over time, exemplified by Figures 4 and 5. The temporal variation of the exposure was strongly pronounced in the individual recordings and was less pronounced in the dining rooms and play hall recordings.

The recordings of pronounced fluctuations of the noise exposure were in agreement with the subjective experiences of the employees. The personnel's subjective experiences

Table 2: Presence and ratings of the physical work environment

	N	Minimum	Maximum	Mean	SD
Noise	92	2	4	3.16	0.58
Ergonomics	93	1	4	2.81	0.70
Temperature	93	1	4	2.57	0.76
Air	92	1	4	2.41	0.81
Lights	93	1	4	2.14	0.84

("1 = not present, 2 = present but not troublesome, 3 = present and somewhat troublesome, 4 = present and very troublesome")



Figure 3: Overview of the average noise levels recorded at the 17 participating preschools

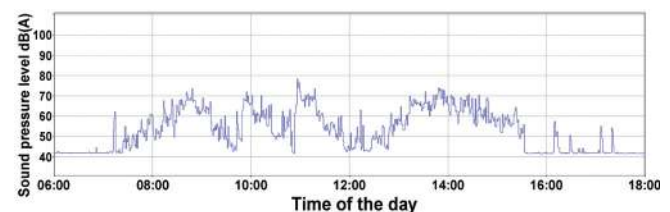


Figure 5: Overview of the level of fluctuations during a noise recording in a play hall (1-min logging. Fast release time)

of fluctuation in the daily noise exposures are described in Table 6.

The events with noise levels exceeding 85 dB(A) are described in Figure 6. As seen from the figure, the presence of strong fluctuations in the noise exposure is highly pronounced during the periods of 09:00 to 11:00 am and 02:00 to 03:00 pm.

The temporal variations during the day reflect activities associated with the morning and afternoon meal. During periods between 12:00 pm and 01:00 am, the numbers of fluctuations are reduced.

#### Number of children and noise exposure

The effects of number of children on the noise levels are described in Figures 7 and 8. According to the linear regression analysis and correlation analysis, both noise levels and fluctuation of the noise exposure were weakly but significantly correlated to the number of children present at the department. Both parameters were increasing with increasing number of children. Positive correlations

were seen for mean number of children during the week and equivalent dB(A) during the week ( $r = 0.240$ ,  $P < 0.05$ ), and also for mean number of children during the week and mean number of sound events during the week ( $r = 0.265$ ,  $P < 0.05$ ).

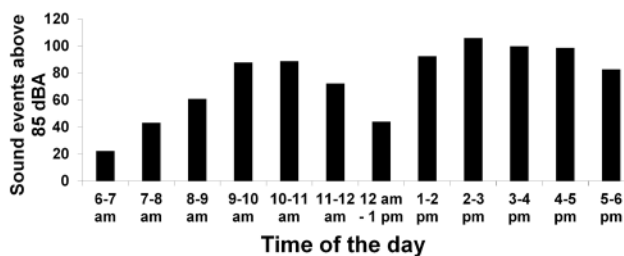
#### Adverse effects

**Hearing Impairment:** The experience of subjective hearing status was asked by in the questionnaire. As seen from Table 7, approximately 46% of the employees considered their hearing to be slightly or strongly impaired.

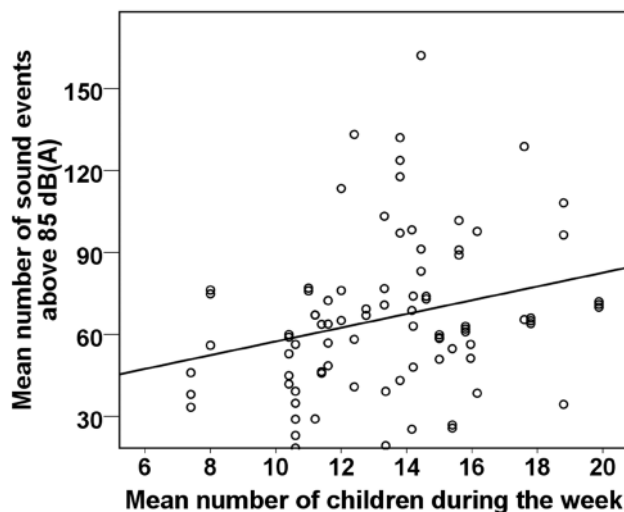
**Table 3: Presence and annoyance ratings of different noise sources**

	N	Minimum	Maximum	Mean	SD
Children's voices	94	2	4	3.28	0.59
Noise from the children's activities	93	2	4	3.04	0.59
Other sounds deriving from the children's activities	93	2	4	3.04	0.55
Porcelain, cutlery	94	1	4	2.78	0.69
Drying cabinet	94	1	4	2.57	0.73

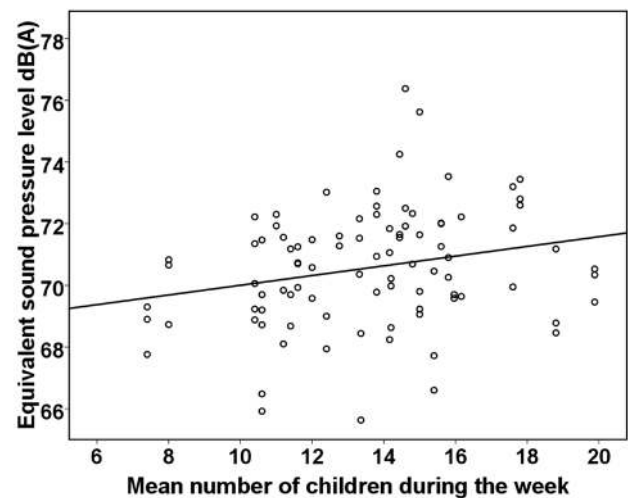
("1 = not present, 2 = present but not annoying, 3 = present and somewhat annoying, 4 = present and very annoying")



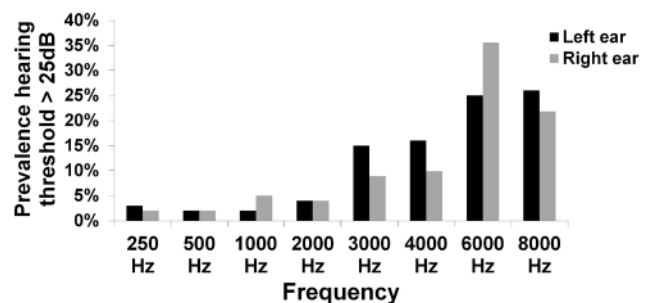
**Figure 6: Mean number of sound events with noise levels above 85 dB(A) during the working day for the 17 participating preschools**



**Figure 8: Scatterplot of the correlation between mean number of noise levels above 85 dB(A) and mean number of children present at the department during the week**



**Figure 7: Scatterplot of the correlation between mean noise levels (personal recordings) and mean number of children present at the department during the week**



**Figure 9: Percent of employees showing hearing thresholds larger than 25 dB on the left and right ear for screened frequencies**



**Table 4: Equivalent (leq) and maximum noise levels during different days of the week**

	Monday (N = 84)	SD	Tuesday (N = 79)	SD	Wednesday (N = 79)	SD	Thursday (N = 86)	SD	Friday (N = 77)	SD
Leq mean dB(A)	70.7	3.4	70.5	2.4	70.7	2.3	70.5	2.2	70.3	2.7
Leq max dB(A)	85.1		81.2		76.7		77.3		79.4	
Mean peak dB(A)	102.7	5.4	103.6	4.1	103.9	3.9	102.7	3.4	102.8	4.6
Max peak dB(A)	116.4		114.7		114.0		112.1		114.3	
Mean peak dB(C)	122.5	6.9	122.7	4.9	122.2	4.9	122.2	4.6	122.1	4.8
Max peak dB(C)	132.4		132.1		132.1		132.4		132.4	

**Table 5: Equivalent (leq) and maximum noise levels in dining rooms and play halls**

	N	Minimum	Maximum	Mean	SD
Dining room leq mean dB(A)	34	59.47	69.80	64.07	2.26
Dining room mean dB(A) max	34	94.33	104.00	97.87	2.22
Play hall leq mean dB(A)	32	55.70	68.50	64.13	2.59
Play hall mean dB(A) max	32	94.65	103.55	98.68	2.08

**Table 6: Personal experiences of fluctuations in the daily noise exposure (“How often do unexpected sudden changes of the sound level occur during the working day?”)**

	Frequency	Percent
Sometimes per week	1	1.1
Several times per week	8	8.6
Sometimes per day	10	10.8
Several times per day	45	48.4
Sometimes per hour	13	14.0
Several times per hour	16	17.2

**Table 7: Participants’ experiences of the subjective hearing status**

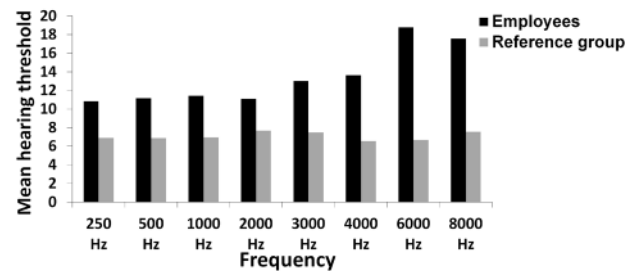
	Frequency	Percent
Fine, no problem	50	53.8
Slightly impaired	40	43.0
Strongly impaired	3	3.2
Total	93	100.0

**Table 8: Tinnitus prevalence among employees (“Do you experience tinnitus?” Other = free text field”)**

	Frequency	Percent
No	64	68.8
Yes, in both ears	19	20.4
Yes, but only in my left ear	2	2.2
Yes, but only in my right ear	3	3.2
Other	5	5.4
Total	93	100.0

The results of the screening of hearing status are described in Figures 9 and 10. The hearing thresholds of the investigated employees were compared with the reference data of Johansson *et al.*<sup>[20]</sup> The prevalence of hearing impairment for the tested frequencies is highest for frequencies 3000 Hz and above [Figure 9]. Six thousand hertz on the right ear shows the highest prevalence of hearing thresholds larger than 25 dB. The 25 dB threshold was applied according to Johansson and Arlinger.<sup>[25]</sup>

None of the employees exceeded the Swedish national

**Figure 10: Average hearing thresholds of the employees on the left and right ear compared with the reference group (50<sup>th</sup> percentile)**

criteria defining a hearing damage.<sup>[24]</sup> None of the employees was remitted to an audiological clinic.

According to Figure 10, the hearing thresholds of the preschool employees exceeded that of the reference group for all tested frequencies. The differences between the investigated preschool employees and the reference groups were significant when using ANOVA analysis for all tested frequencies ( $P < 0.01$ ).

As can be seen in Figure 11, the hearing loss was increasing with age for both the test and the reference group. The influence of noise levels was therefore tested in a correlation matrix.

The correlation between the equivalent dB(A) (personnel recordings) and hearing was significant for the audiometric frequencies 250 Hz ( $r = 0.190$ ), 1000 Hz ( $r = 0.255$ ) and 2000 Hz ( $r = 0.238$ ), ( $P < 0.05$ ).

### Tinnitus

The experiences of tinnitus of the employees are described in Tables 8 and 9. As seen from Table 8, tinnitus was reported among approximately 31% of the employees. In most cases, the symptom was experienced in both ears. 74.2% of the employees with reported tinnitus described the tinnitus as a little bit troublesome and 13.8% described their tinnitus as quite troublesome.

Chi-square analyses was made to test the group differences between tinnitus, subjectively estimated hearing loss and objective audiometric tests. As seen from Table 9, employees with both subjective and objective hearing loss also have a higher prevalence of tinnitus. The group difference was

significant ( $P<0.05$ ) when comparing tinnitus prevalence and estimated hearing loss. The same analysis for the audiometric hearing status indicated a group difference with higher prevalence of tinnitus among employees with a hearing loss; however, this group difference was not significant ( $P=0.065$ ).

The correlation between tinnitus and equivalent dB(A) was not significant, neither was the correlation to the number of sound levels above 85 dB(A).

#### Hyperacusis and diplacusis

Hyperacusis was experienced as “quite often” by 5% of the employees and “sometimes” by 40%. No correlation was found to any of the analyzed noise parameters. None of the employees reported diplacusis as a symptom.

**Table 9: Cross-tabulation of reported tinnitus and hearing loss (“How would you rate your hearing?” and “Do you experience tinnitus?”)**

	No tinnitus (%)	Reported tinnitus (%)
No hearing loss ( <i>subjective</i> )	78.0	22.0
Reported hearing loss ( <i>subjective</i> )	58.1	41.9
No hearing loss ( <i>objective</i> )	78.6	21.4
Reported hearing loss ( <i>objective</i> )	60.8	39.2

**Table 10: Estimations of the masking effect during phone communication**

	Frequency	Percent
I do not speak on the phone during work hours	1	1.1
About 10% of all calls	34	37.4
About 25% of all calls	9	9.9
About 50% of all calls	22	24.2
About 75% of all calls	16	17.6
About 90% of all calls	7	7.7
100% of all calls	2	2.2
Total	91	100.0

**Table 11: Amount of time not being able to perform verbal communication due to masking**

	Frequency	Percent
Never or almost never	8	8.9
About 25% of the time	31	34.4
About 25% of the time	29	32.2
About 50% of the time	17	18.9
About 75% of the time	5	5.6
About 90% of the time	0	0
Total	90	100

**Table 12: Mean value, maximum, minimum and SD of the rated noise annoyance**

	N	Minimum	Maximum	Mean	SD
How annoying in general do you find the sounds at your workplace?	100	23	90	58.07	17.68

#### Masking

The masking effect of the background noise on verbal communication, telephone conversations and overall work situations are described in Tables 10 and 11. The masking effects were strongly pronounced, exemplified by the fact that approximately 24% of the employees considered that about 50% of the phone calls were affected by masking. About 19% of the employees considered that masking affected their communication during 50% of the working hours.

The experiences of masking were not correlated to neither equivalent dB(A) nor mean number of sound events above 85 dB(A). A positive correlation was however seen for masking and the children’s voices. The masking increased in a pronounced way with increasing influence from the children’s voices ( $r = 0.402$ ,  $P<0.01$ ) and sounds from the children’s activities ( $r = 0.323$ ,  $P<0.01$ ).

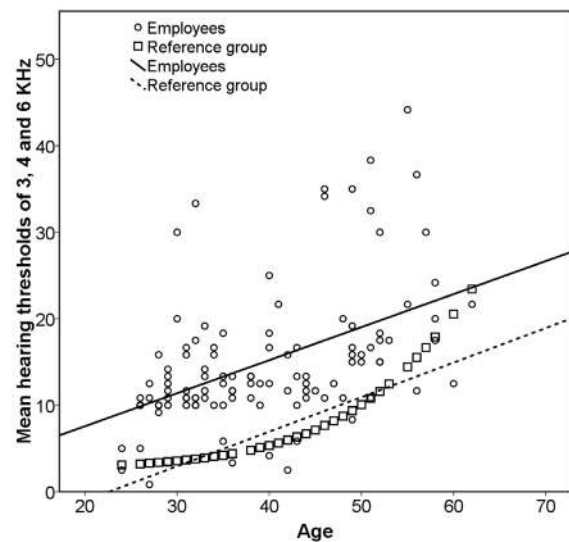
#### Annoyance

The experiences of the dominating noise sources are described in Table 3. Thus, the annoying noise was dominated by the children’s voices and the children’s activities. The annoying noise was rated as “quite disturbing” to “very disturbing” [Figure 12 and Table 12].

The noise annoyance increased with increasing noise level as well with the number of sounds above 85 dB(A). However, the correlation was not significant.

#### Sound fatigue

The experience of sound fatigue was pronounced among the employees. Sound fatigue was related to occur every



**Figure 11: Scatterplot showing the mean hearing thresholds of 3000 Hz, 4000 Hz and 6000 Hz of the employees (dots) and the reference group (squares). Straight line = Linear regression line of the employees, dashed line = Linear regression line of the reference group**

day except weekends, or more among about 30% of the participating employees. About 17% reported sound fatigue to occur almost never or never [Figure 13].

Sound fatigue correlated neither to equivalent dB(A) nor to mean number of noise levels above 85 dB(A). Correlation was found between the sound fatigue and the children's voices ( $r = 0.233$ ,  $P < 0.05$ ). The response of sound fatigue was explained by the same variable as noise annoyance. Consequently, a positive correlation was also seen for sound fatigue and noise annoyance ( $r = 0.285$ ,  $P < 0.01$ ).

The sound fatigue was also increased by the mean number of children at the department. The correlation was close to the level of significance ( $r = 0.167$ ,  $P = 0.055$ ).

#### Voice effects

The experiences of the participating employees on the throat and voice issues are described in Figure 14. According to this figure, about 10–15% of the employees suffered from different types of voice impairment (had to clear their throat, dry throat, etc.). In a correlation analysis, it was found that

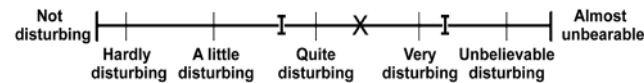


Figure 12: Position of mean value of rated annoyance on the analog scale ( $X = \text{mean}$ ,  $I = \text{SD}$ ) (scale and anchor points according to Lundquist et al. 2000, 2003)<sup>[22,31]</sup>

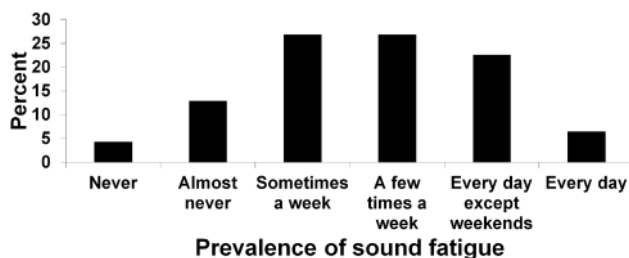


Figure 13: Experiences of sound fatigue among the participating employees ("In what degree do you experience sound fatigue?")

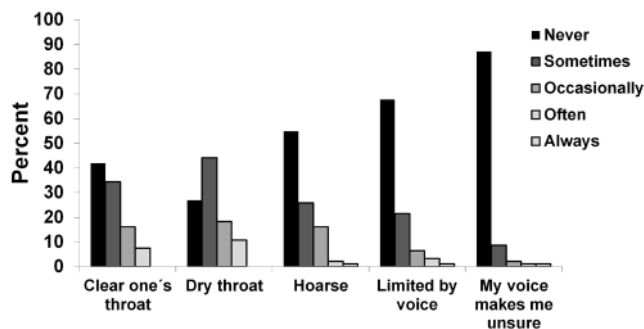


Figure 14: Experiences of voice effects among the investigated employees ("In what degree do you experience throat and voice problems?")

mean equivalent levels dB(A) correlate with hoarse throat ( $r = 0.204$ ,  $P < 0.05$ ). No other voice disorders were found to correlate with neither mean equivalent levels dB(A) or mean number of noise events above 85 dBA.

#### Discussion

The recorded noise levels were in accordance with a number of studies carried out by others.<sup>[1,22,26]</sup> The mean leq levels, as well as the mean maximum and peak values, were remarkably equal in the departments investigated. In all departments, levels were around 70 dB(A). This was also true for the mean leq values of the dining rooms and play halls [both about 64 dB(A)]. The differences between the daily noise levels of the week were also small. According to the statistical analyses made, none of the tested group differences reached a significant level. The outcome can be explained by the uniformity of the daily events at the preschools. The daily activities included the same types of events (procedures for the arrivals of the children, food pauses, indoors and outdoors activities, pauses and rest periods, etc.). The activities were organized in the same way at the participating preschools, as was the time periodicity.

The noise exposures, both recorded as individual exposures and stationary recordings, varied with the number of children present at the departments both as changes during the day and as changes during the days of the week. As expected, the number of children affected the noise exposure. The differences due to number of children however were small. An explanation to that can be found in the way the number of noise sources will affect an equivalent level. Assuming that the contribution from individual children is the same, independent of the total number of children, a reduction to half or increase to the double amount of children per department will cause a change of the leq level by only 3 dB(A). Besides this physically and mathematically based effect, the noise levels of a children group may also be affected by behavioral effects. In most cases, the individual noise level of a child will increase in a larger group.<sup>[27]</sup> The study of Jungua was carried out on adults. We assume that the Lombard effect is also relevant regarding preschool children. The positive correlation between increasing noise levels and number of children can probably be explained as a behavioral effect rather than a summarizing of equal sound levels.

Thus, the differences in noise exposures were very low for all tested group differences. The individual noise exposures however varied a lot, both when comparing individuals and when analyzing the exposures over time. The daily exposures varied between 60 dB(A) and 85 dB(A). In some cases, the individual daily noise exposures exceeded the limit for risk of hearing impairments by 85 dB(A), used by most developed countries, Sweden included.<sup>[28]</sup> For most of the employees, the noise exposures however were below the limit of risk for hearing impairments. An explanation to the varying individual exposures can be found in the way the employees

are engaged in different temporally noisy events during work. E.g., 6-h daily continuous exposure at about 70 dB(A) gives a daily exposure of about 70 dB(A). A time-limited exposure during 30 min at 90 dBA, e.g. during caretaking of a crying child, will increase the daily noise level to about 78 dB(A).

The difference between individual noise exposures and levels recorded in dining and playing rooms were about 6 dB(A). The difference can be explained primarily by the fact that the dosimeters worn by the employees were in closer and more continuous contact with the children compared with the stationary microphones. Besides, in most cases, the dining and playing rooms were used for shorter periods of 1 or 2 h per day. These rooms were not seldom also used for rest and sleep of the children as well as for playing, food intakes and other types of activities. The fact that the two recorded rooms represented equal average noise levels was not surprising. The individual as well as stationary noise exposure varied a lot over time as a result of the children's arrivals and departures and activities carried out. By use of these fluctuations, periods related to noise-related health hazards is possible to localize. Focus then should be pointed to the period between 10.00 am and 3.00 pm, including periods with food pauses and so-called free playing.

A fundamental part of the sound exposure is the rapid fluctuations of the noise. When considering the individual exposure measurements, the fluctuations were more pronounced than in the stationary measurements. As expected, not only the noise levels but also the rapid fluctuations derive from the children's voices and activities. In addition to these sources, phone calls, cutlery and footsteps could be added.

Beside the noise levels and variability of the exposure, the frequency characters of the exposures are of interest. Frequency analyses have not been carried out in the present study. Based on previous studies, the long-term average spectrum frequency of the exposures can be described as dominated by energy in the range of 1000–4000 Hz.<sup>[29]</sup> An explanation to this is that the sound is dominated by the voices of the children. In some of the departments, the ventilation noise was clearly experienced. The experiences of the low-frequency noise by the employees were also noticed in some of the preschools. However, during most of the time and in most of the preschools, the low-frequency noise was masked by the high-frequency parts of the sound exposures.

In the present study, health effects and risk assessments have been focused on auditory effects. The stress and fatigue effects will be presented in a separate publication.

The hearing impairments of the employees were expressed in the evaluations of the questionnaires and in the screenings of the hearing levels (HL). A reduction in HL was observed for all audiometric frequencies. According to the Swedish standardized national evaluation of HL, the reductions found could be described as minor. None of the tested employees

were remitted to an audiologic clinic for further tests. The reduction in hearing thresholds are surprising in the perspective of the relatively low levels of noise exposure. Nevertheless, a positive correlation between noise levels and hearing loss was seen for the audiometric frequencies between 250 Hz and 2000 Hz. Further studies are needed to determine the effects on hearing of impulses and variability of the exposures.

The screening audiograms were carried out in an isolated quiet room at the preschools with 10 dB sensitivity. The clinic audiogram for the reference group was carried out with a sensitivity of 0 dB. However, it is unlikely that the differences in the thresholds between the employees and the reference group could be explained by the audiometric setups.

The symptoms of tinnitus among the participants exceeded the occurrence of an average population by about 20%.<sup>[6–8]</sup> However, the comparison regarding tinnitus prevalence is difficult due to differences in defining tinnitus. No correlation was found to the noise exposure.

Speech and listening are central aspects of the preschool work. In so, masking might be a severe effect, making work more difficult and with higher efforts as a consequence. The background noise, mainly built up by the children's voices, makes masking of the relevant speech especially effective.<sup>[30]</sup> The employees' noise annoyance was rated relatively high and was primarily caused by the children's voices and activities. The annoyance responses of the employees can be explained by a number of isolated and cooperating parameters. The noise levels are highly masking, the noise involves a high degree of fluctuations, the frequency of the noise is built up in the range with the highest hearing sensitivity, the noise is dominated by voice and the work carried out is highly sensitive to noise exposures. The contribution of low-frequency noise to annoyance can be found in the way this additional noise increases the general sound level at the departments.<sup>[31]</sup> The background low-frequency noise also increases the risk of fatigue responses among the employees.<sup>[31]</sup>

The voice effects observed among the participants are supported by a number of recent studies<sup>[19]</sup> and are the result of the necessity to raise the voice level in the noise environment. The risk of chronic impairments is of special importance.

The noise exposure of the employees at the preschools influences a number of auditory reactions. A well-grounded assumption would be that both hearing and other types of auditory ill health, such as sound fatigue and annoyance, are highly affected by combinations of several noise parameters. The influences of the variability of the exposures are of special importance. The interactions to work, stress reactions and fatigue are other variables that have to be taken into account when evaluating the noise exposure and ill-health of the employees.



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