WORLD HEALTH ORGANIZATION
EUROPE

WHO LARES

Final report

Noise effects and morbidity

By:
Dr Hildegard Niemann / Dr Christian Maschke
Interdisciplinary research network
„Noise and Health“

BZPH Berlin Center of Public Health

ABSTRACT

This document represents the final report of an analysis on the health effects of noise exposure. The analysis is based on the WHO Large Analysis and Review of European housing and health Status (LARES), which combines the data of eight city studies in European countries. It was presented at a WHO housing and health technical meeting on the analysis of evidence, and was subject to peer review by other analysis teams of the LARES study and three external reviewers.

The document presents the analytical approach and the statistical procedures used for assessing the impact of residential noise exposure on noise induced annoyance and noise induced sleep disturbances. Split into traffic noise and neighbourhood noise for annoyance. The results are identified individually for children, adults and elderly, acknowledging that each age group is affected by noise in a different way and consequently shows a different pattern of morbidity potentially related to noise subjective exposure.

One of the main conclusions of this work is that for noise induced sleep disturbances, traffic noise annoyance and neighbourhood noise annoyance, the identified health effects are independent of socio-economic status and housing conditions. The elevated relative risks are expressed in the cardiovascular system, the respiratory system and the musculoskeletal system, as well as through depression.

Keywords

NOISE
NOISE EFFECTS
RESIDENTIAL NOISE EXPOSURE
HOUSING
ENVIRONMENTAL HEALTH
ANNOYANCE
SLEEP DISTURBANCE

CONTENTS

Noise effects and morbidity

Introduction

Environmental noise, irrespective of its source – road, rail or air traffic, or neighbourhood activities – remains a key issue in most European countries.
The predominant health effect of noise is auditory damage which includes hearing loss. This is frequently caused by loud work noise or by loud music (i.e. from continuous high exposure to walkmans and discotheques) as well as by loud fireworks. But besides these auditory noise effects attention must also be paid to the non-auditory effects of noise. Non-auditory effects of noise appear to occur at levels far below those required to damage the hearing organ.

Environmental noise acts as a stressor at night by disturbing sleep and via annoyance (or bothering) during the day.

The effect of environmental noise on sleep and annoyance were included as were several morbidities in the LARES study. The final report examines the strength of the association between noise induced annoyance or noise induced sleep disturbances with stress mediated diseases.

Data processing

The examination of the statistical association between noise annoyance as well as noise induced sleep disturbances and diseases must do justice to the fact, that both diseases and risk factors are affected by many other factors other than noise. Therefore, for a meaningful statistical analysis multiple methods must be applied, orientated by the knowledge of noise effect research, the underlying pathogenesis model and the scale level of the collected variables. With respect to the different health end-points the control variable set has to be regarded as less complete. Therefore a careful interpretation of the statistical effects is necessary.

Logistic regression

In all analysis, multiple logistic regressions were used. Normally, a logistic regression is used to analyse an event which may or may not occur (e. g. fall ill or not, medical treatment or not). By means of the logistic regression an estimator (“odds ratio”, OR) for the relative risk of the occurrence of an event depending on the examined factor (e. g. sleep disturbance) was calculated taking into consideration other influence factors (control variables).
Odds Ratios (OR) were calculated as an estimator of the relative risk (RR) of the occurrence of an event (e. g. prevalence of a disease) and its dependents on the examined factor (disturbances) and maybe other influencing factors (Confounder, moderator).

Control variables

In total, 16 control variables were included in the logistic regression, which, in the case of the diseases, are assumed to influence the result. The well known control variables “age”, “gender”, “consumption of alcohol”, “smoking behaviour”, “sports”, “body mass index”, and the “social-economic state” were completed by housing factors. To identify housing factors from the large housing und health questionnaire a dimension testing was carried out in the form of a factor analysis (SPSS 11.0). According to the factor analysis six relevant housing dimensions were extracted.
In Table 1 the six housing dimensions are introduced by factor labels together with the variables used in the statistical calculations to control the housing factors. The presented control variables were suggested by the competent expert groups. Otherwise the variable correlating most strongly with the extracted factor was used.

Table 1: Housing and health dimensions extracted by factor analysis and control variables used in the statistical calculations

Factor labels	**Control variables**
Inner housing factor: **dampness in dwelling**	Total mould rating (Mouldy2)
Inner housing factor: **air quality in dwelling**	Air quality in dwelling (aq_1)
Outside housing factor: **green areas**	Visible vegetation in housing environment (he_6_1)
Outside housing factor: **Satisfaction with residential areas**	Residential areas (iesc4gr)
Inner housing factor: **temperature and heating in winter**	Problem with temperature in winter (t_7_1)
Inner housing factor: **daylight in dwelling**	Need to turn on light (li_1)

Furthermore the different European cities of the LARES study were taken into account as additional control variable (city_nr) as well as their averaged temperatures (av°c_yea) and humidities (rh_av).

Effect of noise annoyance

A central effect of noise is annoyance. Annoyance is defined as a feeling of discomfort which is related to adverse influencing of an individual or a group by any substances or circumstances. Annoyance express itself e. g. by malaise, fear, threat, trouble, uncertainty restricted liberty experience, excitability or defencelessness. With chronically strong annoyance a causal chain may exist between the three steps health - annoyance - disease.

By means of the questions „Thinking about the last 12 month, when you are here at home, how much would you say that noise from following sources bothers or annoys you?”, the individual annoyance by out-door and indoor noise sources was determined. The percentage frequency of different noise sources which bothers or annoys is presented in including the intensity of the effect.

To fill in the LARES-questionnaire regarding noise annoyance, it is necessary to be aware of the annoyance. That is not always the case for sleeping persons and a general problem for younger

children. Annoyance therefore has a closer link with day time noise and the interpretation could be difficult in young children.

The individual annoyance from road noise, airplane noise, train noise, as well as parking noise, were summarized to examine the effect of traffic noise altogether, because traffic noise is one of the predominant noise source in the living environment. The second major noise source is the neighbourhood. General annoyance from neighbourhood noise was therefore additionally summarized by neighbour flat, staircase, playing children, as well as by noise within dwelling. Both sum scores were subdivided into 3 categories (with the expressions: not at all, moderately and strongly (cut-off point 8)). The 3-scale variables, simply called traffic annoyance and neighbourhood annoyance were subsequently used for the analyses carried out with disturbance and annoyance. The percentage frequency of each 3-scale variable is presented in Figure 2.

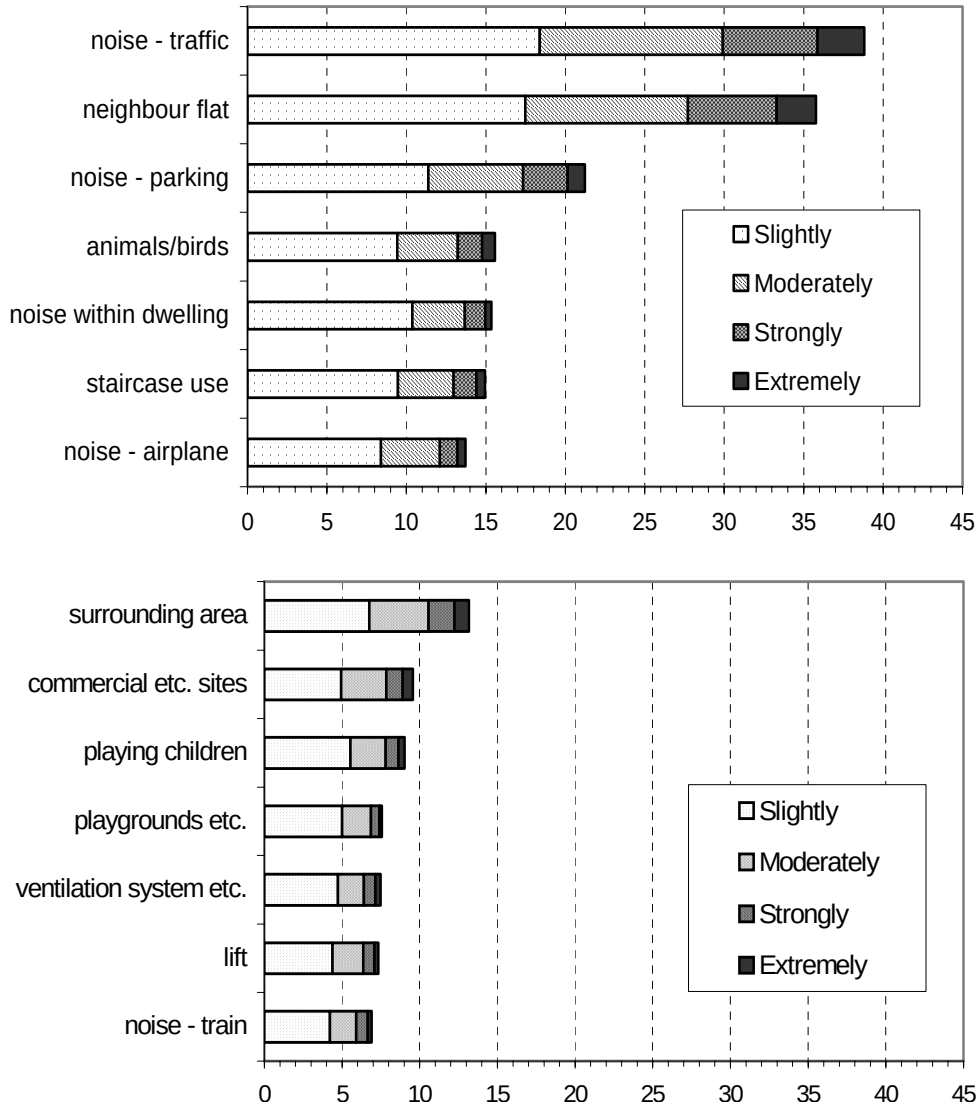

Figure 1: Percentage frequency of different sources which bothers or annoys adults, children and elderly (in 4 scales: slightly, moderately, strongly, extremely) N = 7949

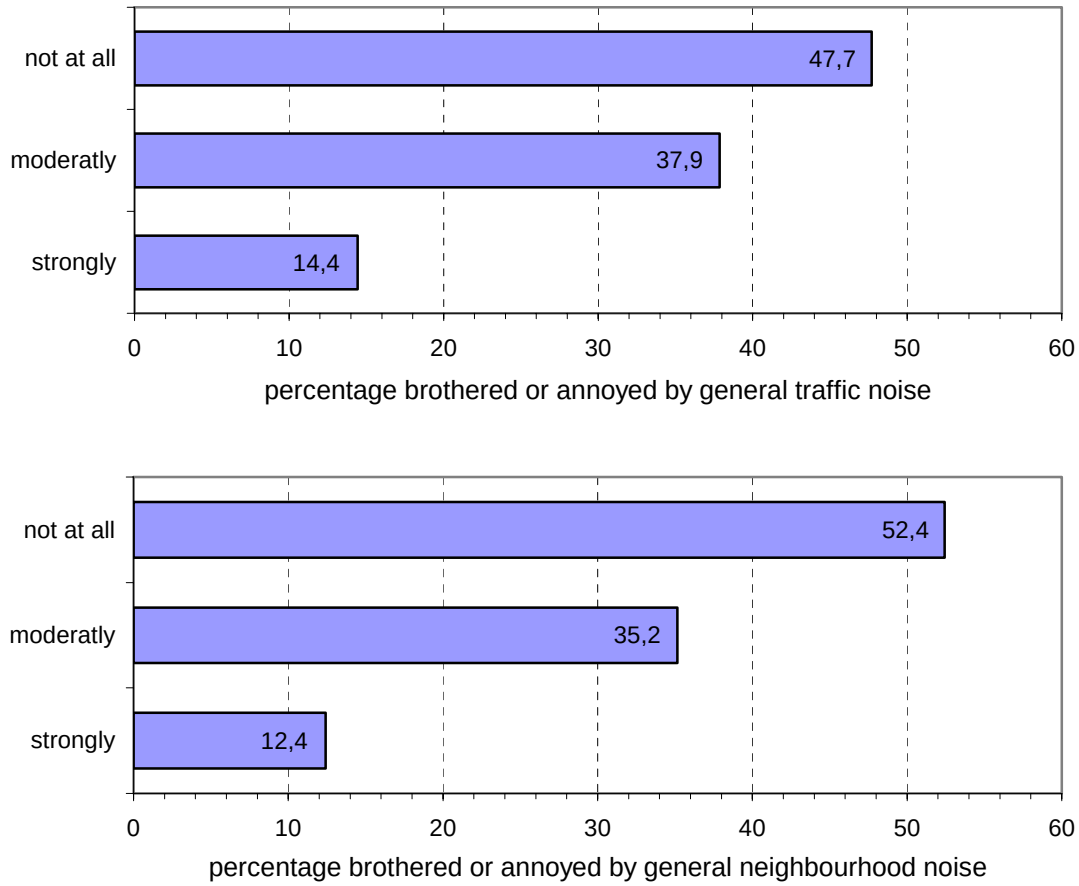

Figure 2: Percentage frequency for general traffic noise (road, airplane, train, and parking noise) (N = 7817) as well as for general neighbourhood noise (neighbour flat, staircase, playing children, and noise within dwelling) (N=7789) for all valid cases (adults, children and elderly)

Adults

In the following figures the Relative Risk of diseases (Odds Ratio) including the 95% confidence interval are represented for such adults (18-59 years) who indicated annoyance by traffic or neighbourhood noise, in comparison with a reference group. For annoyance by traffic noise the reference group are adults without traffic noise induced annoyance, for annoyance by neighbourhood the reference group are adults without neighbourhood noise induced annoyance. The Relative Risks are statistically significant if the drawn confidence interval did not include the value 1. Note that for adults the correlation between traffic noise induced annoyance and neighbourhood noise induced annoyance is significant but low (r=0.29). The variables are therefore not statistically independent but the overlapping variance is less than 9%.

The evaluation of the effect of moderate annoyance by general traffic noise shows for asthma, diabetes, and migraine slight but significantly elevated disease risk (see Figure 4). With the complexities of arthritic, respiratory and cardiovascular (CV) symptoms, disease symptoms are additional collected for the musculoskeletal and the respiratory system as well as for the cardiovascular system. Furthermore, the complex of SALSA considers the "trend to depression".

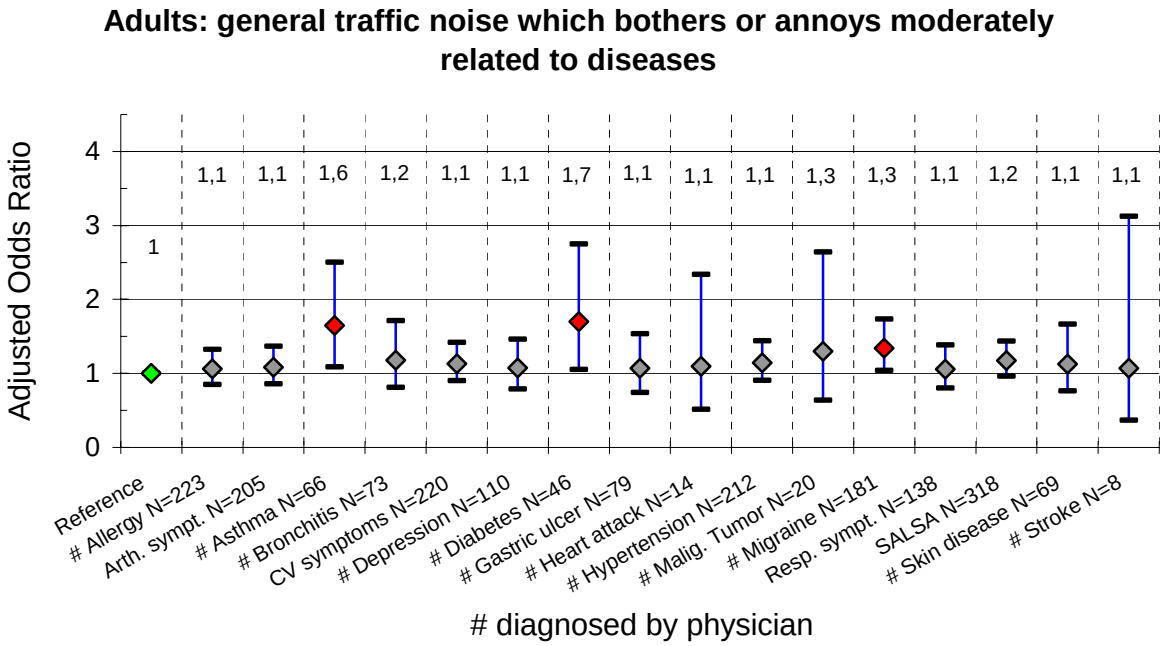

Figure 3: Relative disease risks for adults who indicated moderate noise induced annoyance by general traffic noise within the last 12 months, in comparison with adults without noise induced annoyance. Adjusted for "age", "gender", "socio-economic state", "consumption of alcohol", "smoking behaviour", "sports", "body mass index", “dampness in dwelling”, “air quality in dwelling”, “winter temperature in dwelling”, “daylight in dwelling”, “green areas”, “satisfaction with residential areas”, "cities", "averaged outdoor temperature", and "averaged outdoor humidity” (N=3279).

The evaluation of the effect of strong annoyance by general traffic noise reveals that annoyance could be a serious risk factor for many of the examined health endpoints (see Figure 4). For Asthma, diabetes, gastric ulcer, heart attack, malignant tumour, skin disease and stroke there is no significant increased risk.

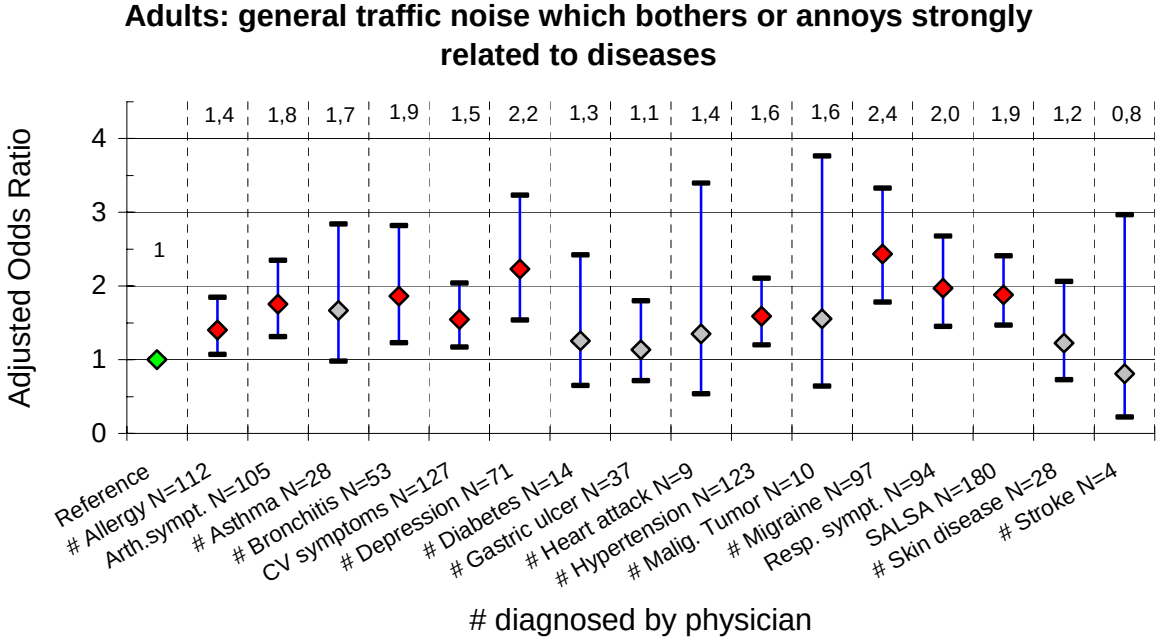

Figure 4: Relative disease risks for adults who indicated strong noise induced annoyance by general traffic noise within the last 12 months, in comparison with adults without noise induced annoyance. Adjusted for "age", "gender", "socio-economic state", "consumption of alcohol", "smoking behaviour", "sports", "body mass index", “dampness in dwelling”, “air quality in dwelling”, “winter temperature in dwelling”, “daylight in dwelling”, “green areas”, “satisfaction with residential areas”, "cities", "averaged outdoor temperature", and "averaged outdoor humidity”” (N=2163).

The evaluation of the effect of general neighbourhood noise show that not only traffic noise could influence the health risk, and that the risk pattern for strong annoyance is nearly the same as for traffic noise.
With moderate annoyance by general neighbourhood noise the relative risks for allergy, arthritic symptoms, CV-symptoms and hypertension are significantly but slightly increased (see Figure 5), whereas by traffic noise the risks asthma, diabetes, and migraine are slightly elevated.

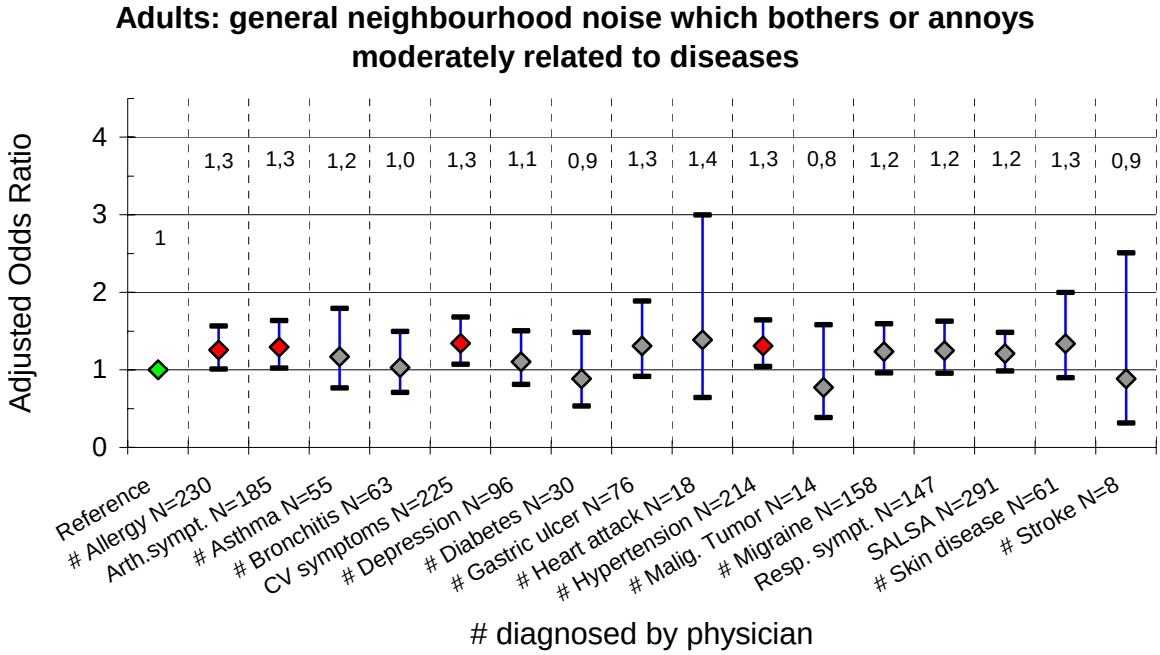

Figure 5: Relative disease risks for adults who indicated moderate noise induced annoyance by general neighbourhood noise within the last 12 months, in comparison with adults without neighbourhood noise induced annoyance. Adjusted for "age", "gender", "socio-economic state", "consumption of alcohol", "smoking behaviour", "sports", "body mass index", “dampness in dwelling”, “air quality in dwelling”, “winter temperature in dwelling”, “daylight in dwelling”, “green areas”, “satisfaction with residential areas”, "cities", "averaged outdoor temperature", and "averaged outdoor humidity” (N=3402).

Strong annoyance by general neighbourhood noise is associated with significant and high increased risks for many diseases. For diabetes, gastric ulcer, heart attack, malignant tumour, and stroke there is no statistical association and significance is just missed for Asthma and skin disease.

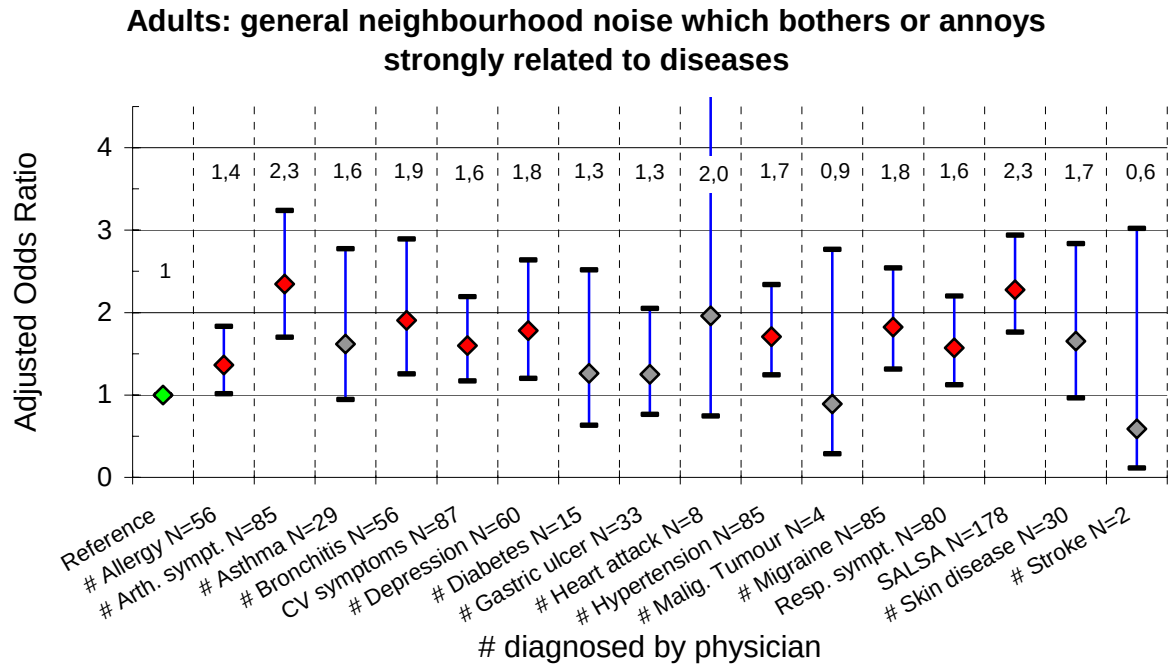

Figure 6: Relative disease risks for adults who indicated strong noise induced annoyance by general neighbourhood noise within the last 12 months, in comparison with adults without neighbourhood noise induced annoyance. Adjusted for "age", "gender", "socio-economic state", "consumption of alcohol", "smoking behaviour", "sports", "body mass index", “dampness in dwelling”, “air quality in dwelling”, “winter temperature in dwelling”, “daylight in dwelling”, “green areas”, “satisfaction with residential areas”, "cities", "averaged outdoor temperature", and "averaged outdoor humidity” (N=2227).

Children

Many function systems of little children (e.g. the nervous system and the cognitive system) are subject to rapid growth and development. The development of the child is not designed to compensating for high environmental noise exposure. Therefore children could be a risk group regarding the effect of noise annoyance on health.

In the following figures the Relative Risk of diseases (Odds Ratio) including the 95% confidence interval are represented for such children (1-17 years) who indicated annoyance by traffic or neighbourhood noise, in comparison with a reference group. For annoyance by traffic noise the reference group are children without traffic noise induced annoyance, for annoyance by neighbourhood noise the reference group are children without neighbourhood noise induced annoyance. The Relative Risks are statistically significant if the drawn confidence interval did not include the value 1.

Hypertension, heart attack, gastric ulcer, malignant tumour and stroke are diseases whose prevalence increase with age and therefore in children only appear rarely. The low number of cases did not allow a meaningful logistical regression. A second problem is the annoyance rating from younger children. We assume that the annoyance rating by children is meaningful if children are 10 years or older. Therefore, for the younger children we use the averaged annoyance rating of all adults in the household.

Note that for children the correlation between traffic noise induced annoyance and neighbourhood noise induced annoyance is greater than for adults (r=0,366). The variables therefore are not independent but the overlapping variance is less than 13%.

Moderate annoyance by general traffic noise in Children (0-17 years) is associated with elevated risks for respiratory symptoms (RR=1.8) and SALSA (trend of depression, RR=1.8) (Figure 7).

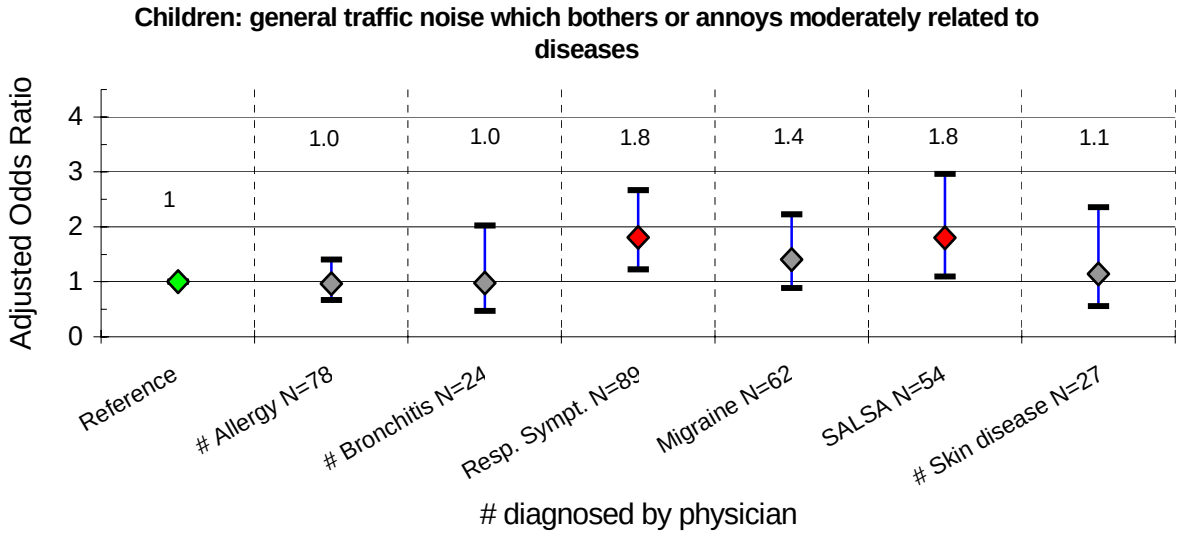

Figure 7: Relative disease risks for children who indicated moderate noise induced annoyance by general traffic noise within the last 12 months, in comparison with children without traffic noise induced annoyance. Adjusted for "age", "gender", "socio-economic state", "consumption of alcohol", "smoking behaviour", "sports", "body mass index", “dampness in dwelling”, “air quality in dwelling”, “winter temperature in dwelling”, “daylight in dwelling”, “green areas”, “satisfaction with residential areas”, "cities", "averaged outdoor temperature", and "averaged outdoor humidity”. Note: SALSA is not validated for children (N=1195).

The examination of strong annoyance by general traffic noise shows that children fall 2.6 times more ill with bronchitis, than not traffic noise annoyed children. The Relative Risks for respiratory symptoms (RR=2.6) and SALSA are considerable increased but for SALSA (trend to depression) the significance is just missed (see Figure 8).

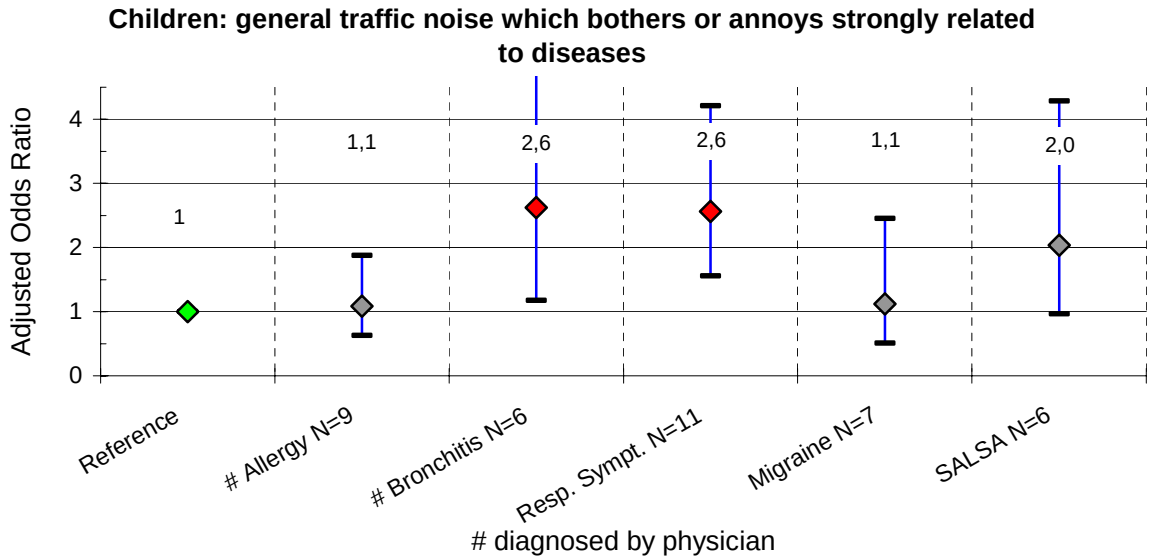

Figure 8: Relative disease risks for children who indicated strong noise induced annoyance by general traffic noise within the last 12 months, in comparison with children without traffic noise induced annoyance. Adjusted for "age", "gender", "socio-economic state", "consumption of alcohol", "smoking behaviour", "sports", "body mass index", “dampness in dwelling”, “air quality in dwelling”, “winter temperature in dwelling”, “daylight in dwelling”, “green areas”, “satisfaction with residential areas”, "cities", "averaged outdoor temperature", and "averaged outdoor humidity”. Note: SALSA is not validated for children (N=720).

Moderate annoyance by general neighbourhood noise in Children (0-17 years) is associated with elevated risks for respiratory symptoms (RR=1.6) and skin disease RR=3.1), but the risk of skin disease are accompanied by a large confidential interval (see Figure 9).

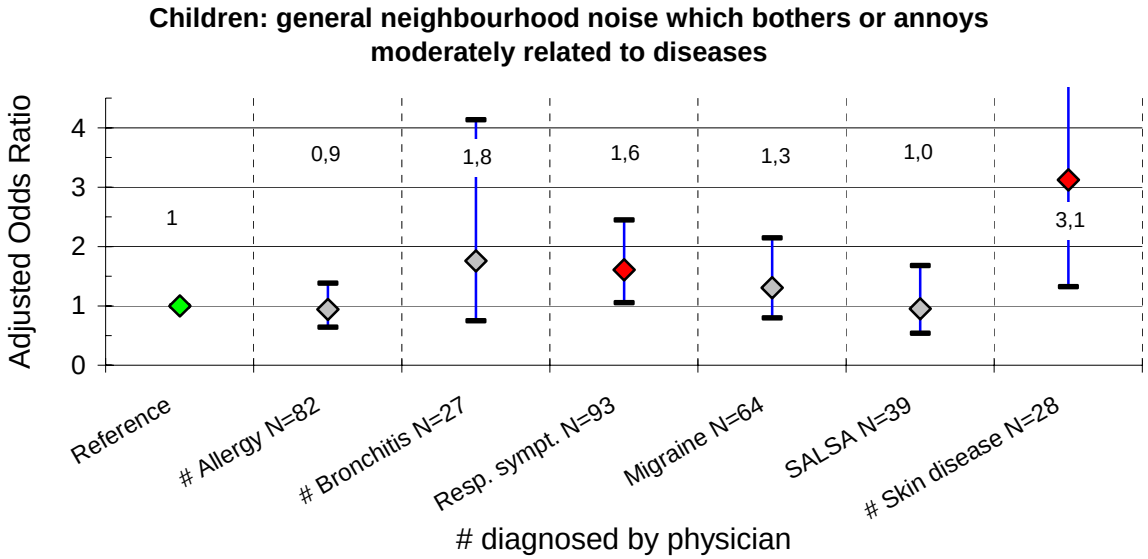

Figure 9: Relative disease risks for children who indicated moderate noise induced annoyance by general neighbourhood noise within the last 12 months, in comparison with children without neighbourhood noise induced annoyance. Adjusted for "age", "gender", "socio-economic state", "consumption of alcohol", "smoking behaviour", "sports", "body mass index", “dampness in dwelling”, “air quality in dwelling”, “winter temperature in dwelling”, “daylight in dwelling”, “green areas”, “satisfaction with residential areas”, "cities", "averaged outdoor temperature", and "averaged outdoor humidity”. Note: SALSA is not validated for children (N=1155).

Strong annoyance by general neighbourhood noise is associated with significant and considerably high increased risks for bronchitis (RR=3.5), respiratory symptoms (RR=2.6), migraine (RR=2.2), SALSA (RR=3.3) and skin disease (RR=3.0), but the risk of bronchitis and skin disease are accompanied by large confidential intervals (see Figure 10).

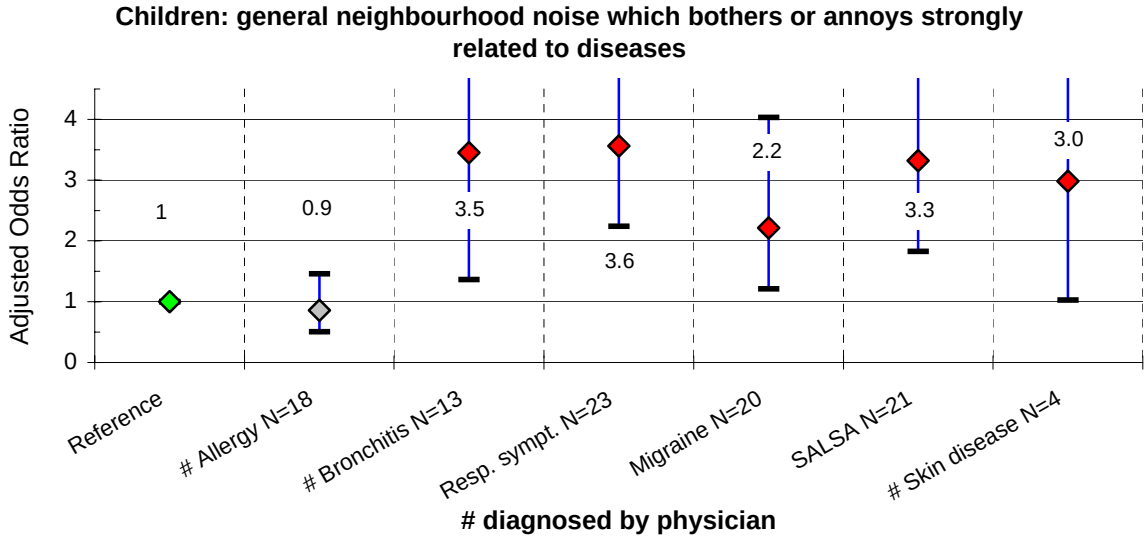

Figure 10: Relative disease risks for children who indicated strong noise induced annoyance by general neighbourhood noise within the last 12 months, in comparison with children without neighbourhood noise induced annoyance. Adjusted for "age", "gender", "socio-economic state", "consumption of alcohol", "smoking behaviour", "sports", "body mass index", “dampness in dwelling”, “air quality in dwelling”, “winter temperature in dwelling”, “daylight in dwelling”, “green areas”, “satisfaction with

residential areas", "cities", "averaged outdoor temperature", and "averaged outdoor humidity". Note: SALSA is not validated for children (N=660).

Elderly

From general stress research it is well known, that the ability to cope with noise is decreased in the elderly. Therefore elderly people could be a risk group regarding noise annoyance and health. In the following figures the Relative Risk of diseases (Odds Ratio) including the 95% confidence interval are represented for such elderly people (60 and older) who indicated annoyance by traffic or neighbourhood noise, in comparison with an elderly reference group. For annoyance by traffic noise the reference group are elderly people without traffic noise induced annoyance, for annoyance by neighbourhood noise the reference group are elderly people without neighbourhood noise induced annoyance. The Relative Risks are statistically significant if the drawn confidence interval did not include the value 1. Note that the correlation between traffic noise induced annoyance and neighbourhood noise induced annoyance is low for elderly people (r=0,271). The variables therefore are not independent but the overlapping variance is less than 8%.

For elderly people (60 years and older) the examination shows that strong annoyance by traffic noise is a significant risk factor only for arthritic symptoms (RR=2.1) and stroke (RR=2.7). That is nearly the same for strong annoyance by neighbourhood noise (RR=2.1; 2.4), but with neighbourhood noise the risks for gastric ulcer (RR=3.7) and depression (RR=2.0) are in additional significantly elevated (see Figure 11). It seems that in comparison with adults for elderly people other factors than noise annoyance is more decisive for the appearance of a disease.

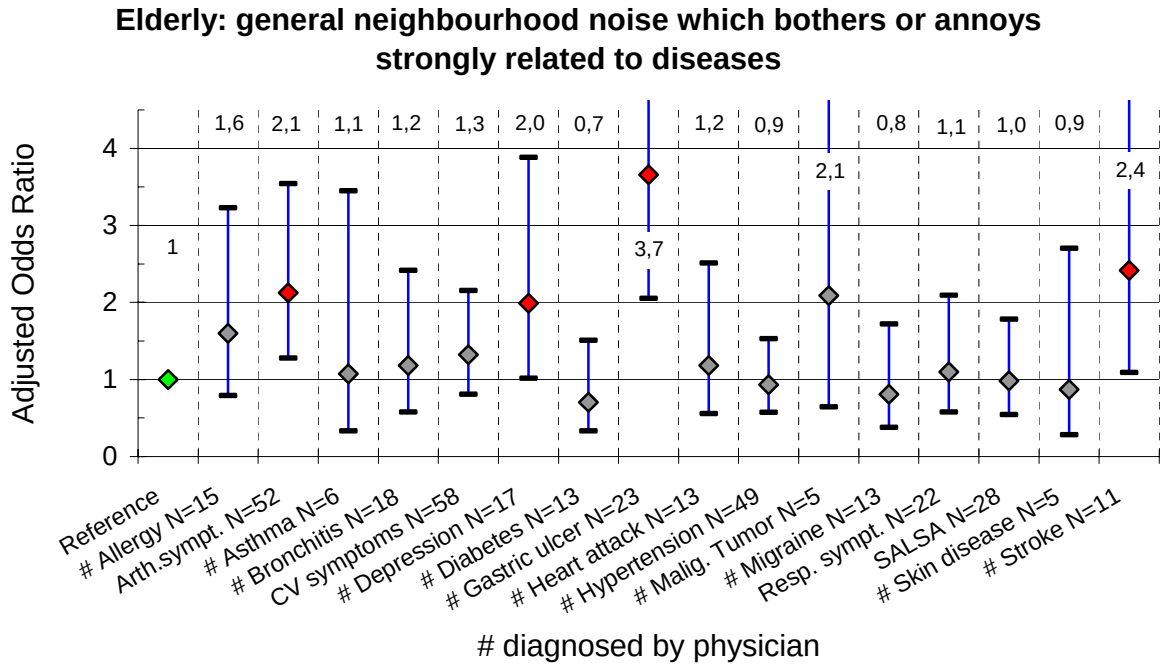

Figure 11: Relative disease risks for elderly people who indicated strong noise induced annoyance by general neighbourhood noise within the last 12 months, in comparison with elderly people without neighbourhood noise induced annoyance. Adjusted for "age", "gender", "socio-economic state", "consumption of alcohol", "smoking behaviour", "sports", "body mass index", "dampness in dwelling", "air quality in dwelling", "winter temperature in dwelling", "daylight in dwelling", "green areas", "satisfaction with residential areas", "cities", "averaged outdoor temperature", and "averaged outdoor humidity" (N=936).

Effect of noise induced disturbed sleep

Sleep is an essential condition for humans and can be severely disturbed by noise. Acute sleep disturbances affect the subjective wellbeing and with an individual latency, also affect qualitative or quantitative performance. Chronic forms of sleep disorders are frequently classified as a health risk.
It is well known that sleep can be disturbed by noise exposure. The effect of noise induced sleep disturbances was analysed by means of the question “Has your sleep been disturbed by noise during the past 4 weeks?”. The percentage of sleep disturbances regarding different noise sources is presented in
Figure 12.

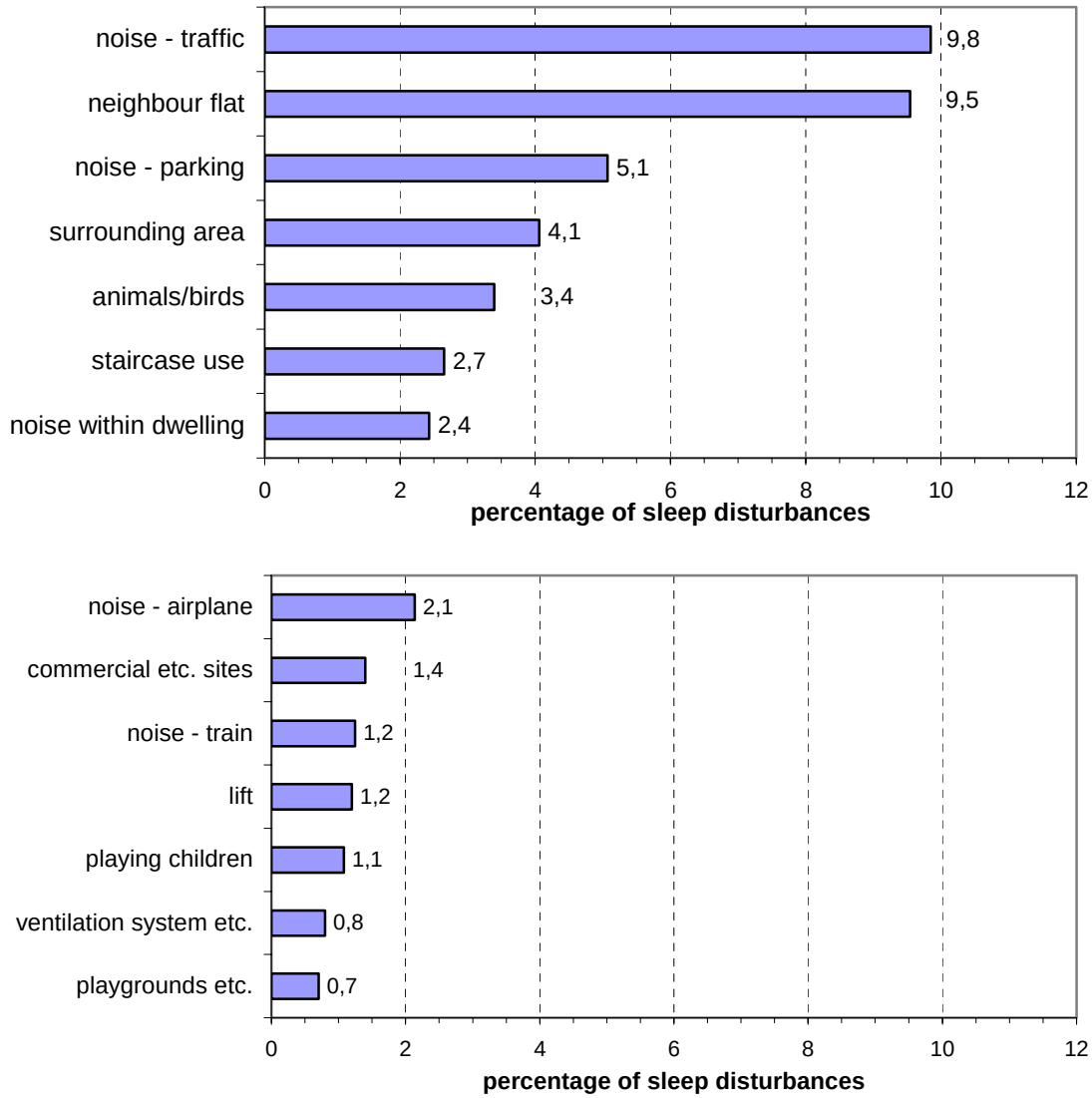

Figure 12: Percentage frequency of noise sources which induced sleep disturbances N = 8519 (adults, children and elderly)

The percentage distribution of noise induced sleep disturbances is presented in Figure 13.

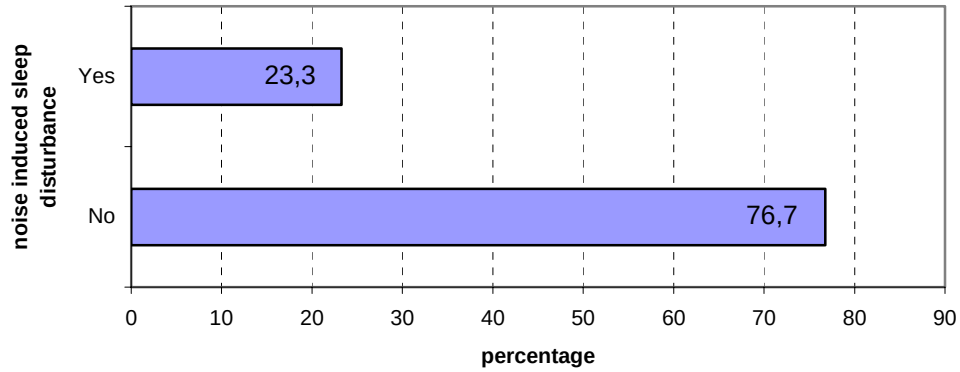

Figure 13: Percentage distribution of noise induced sleep disturbances in the whole sample (N = 8325)

Adults

In the following figure the Relative Risk of diseases (Odds Ratio) including the 95% confidence interval are represented for such adults (18-59 years) who indicated noise induced sleep disturbances by noise, in comparison with adults without noise induced sleep disturbances. The Relative Risks are statistically significant if the drawn confidence interval did not include the value 1.

The noise induced sleep disturbances are associated for adults with significantly elevated risks for the vast majority of diseases. Only for diabetes, malignant tumour, skin disease and stroke no remarkable association were calculated. Furthermore, significance is missed at heart attack (see Figure 14).

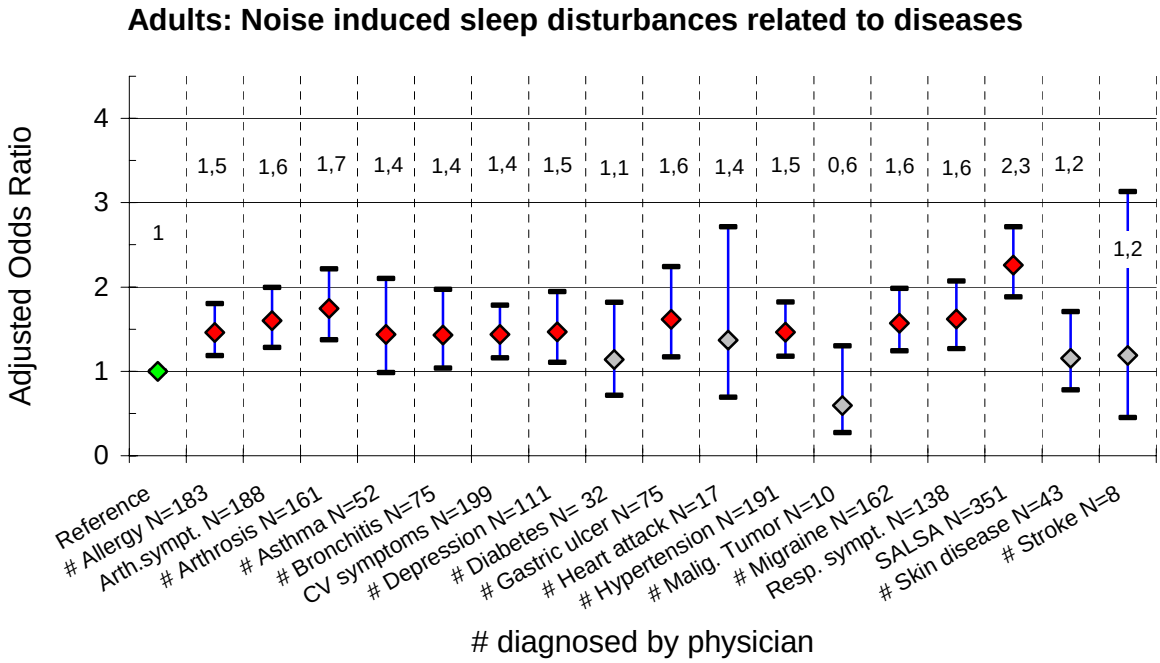

Figure 14: Relative disease risks for adults which indicated noise induced sleep disturbances within the last 4 weeks in comparison with adults without noise induced sleep disturbances. Adjusted for "age", "gender", "socio-economic state", "consumption of alcohol", "smoking behaviour", "sports", "body mass index", “dampness in dwelling”, “air quality in dwelling”, “winter temperature in dwelling”, “daylight in dwelling”, “green areas”, “satisfaction with residential areas”, "cities", "averaged outdoor temperature", and "averaged outdoor humidity” (N=4309).

Children

The sleep structure and the sleep quality change dramatically in the course of childhood. Therefore children could be a risk group regarding noise induced sleep disturbances.

In the following figure the Relative Risk of diseases (Odds Ratio) including the 95% confidence interval are represented for such children (1-17 years) who indicated noise induced sleep disturbances, in comparison with children without noise induced sleep disturbances. We assume for the analysis that the rating for noise induced sleep disturbances is more or less reliable for all children. The Relative Risks are statistically significant if the drawn confidence interval did not include the value 1.
With children noise induced sleep disturbances are statistically associated with a highly elevated risk of medical treatments due to bronchitis (RR=3.7) as well as with elevated risks for respiratory symptoms (RR=1.9) and for ”trend of depression” (SALSA, RR=3.5). For headaches and migraines, it is well known that in the case of children physicians are consulted only rarely. Therefore, in the following Figure 15 noise induced sleep disturbances with self reported migraine were examined. The amount of cases of self reported migraines was more than doubled in comparison to migraines diagnosed by a physician. Children with noise induced sleep disturbances fall 2.2 times more ill with migraines. The strongest association was calculated for arthritic symptoms. Children with noise induced sleep disturbances have 7.3 times more arthritic symptoms, but the risk is accompanied by an very large confidential interval (CI=2.4-22.2).

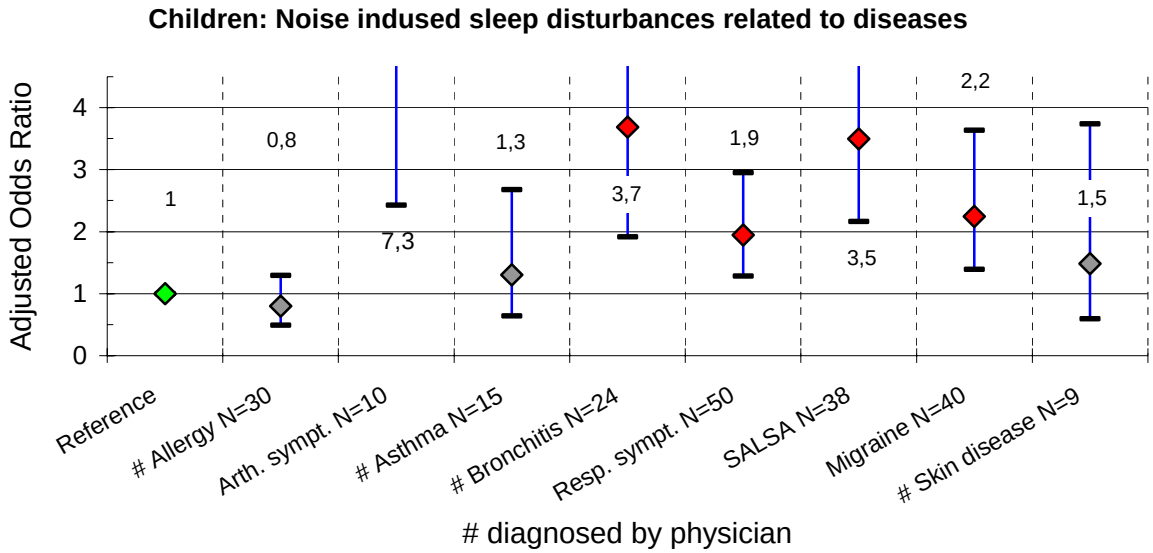

Figure 15: Relative disease risks for children which indicated noise induced sleep disturbances within the last 4 weeks in comparison with children without noise induced sleep disturbances. Adjusted for "age", "gender", "socio-economic state", "consumption of alcohol", "smoking behaviour", "sports", "body mass index", “dampness in dwelling”, “air quality in dwelling”, “winter temperature in dwelling”, “daylight in dwelling”, “green areas”, “satisfaction with residential areas”, "cities", "averaged outdoor temperature", and "averaged outdoor humidity”. Note: SALSA is not validated for children (N=1274).

Elderly

Sleep quality decreases strongly in elderly people. Therefore elderly people could be a risk group regarding noise induced sleep disturbances.

In the following figure the Relative Risk of diseases (Odds Ratio) including the 95% confidence interval are represented for such elderly people (1-17 years) who indicated noise induced sleep disturbances, in comparison with elderly people without noise induced sleep disturbances. The Relative Risks are statistically significant if the drawn confidence interval did not include the value 1.
With elderly people noise induced sleep disturbances are statistically associated with arthritic symptoms (RR=1.6), asthma (RR=2.0), gastric ulcer (RR=2.2) migraine (RR=1.7) and SALSA (RR=1.4).

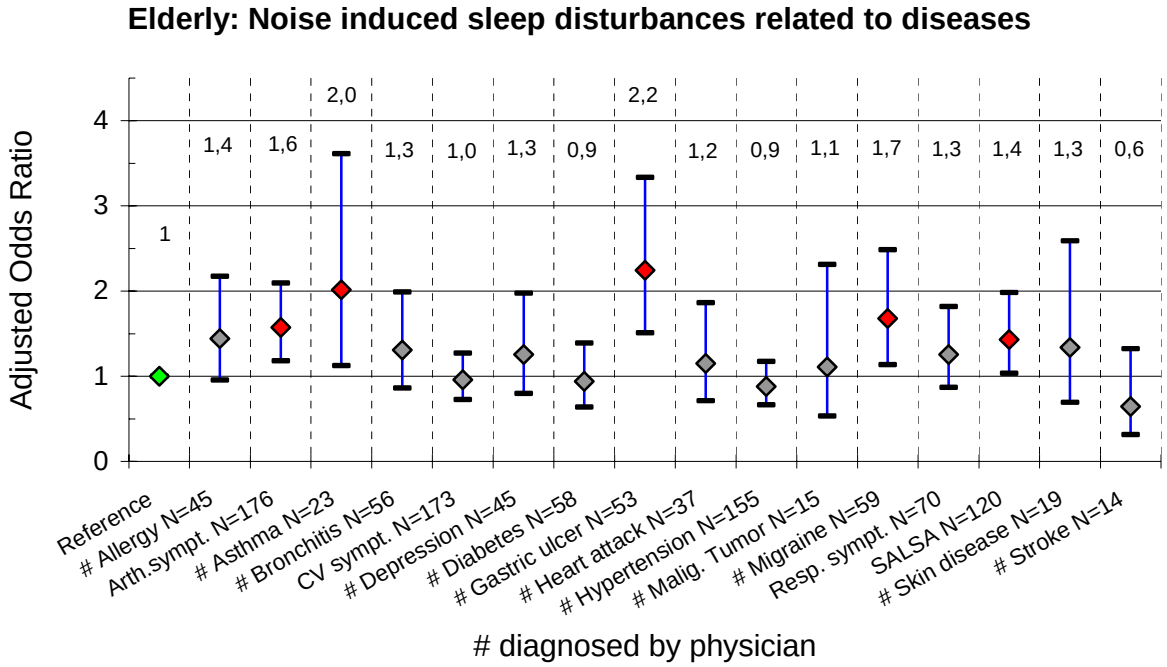

Figure 16: Relative disease risks for the elderly which indicated noise induced sleep disturbances within the last 4 weeks in comparison with elderly people without noise induced sleep disturbances. Adjusted for "age", "gender", "socio-economic state", "consumption of alcohol", "smoking behaviour", "sports", "body mass index", “dampness in dwelling”, “air quality in dwelling”, “winter temperature in dwelling”, “daylight in dwelling”, “green areas”, “satisfaction with residential areas”, "cities", "averaged outdoor temperature", and "averaged outdoor humidity” (N=1404).

Discussion

For noise effect research the disease as a pathological health end-point is of high importance and can only be examined in epidemiological studies. In epidemiological studies, like the LARES study, however only statistical associations can be uncovered. The assessment, whether a calculated association reflects a causal relation has to be carried out according to different criteria. After exclusion of chance, bias and confounding, the strength of the association, expressed by the relative risks, as well as the biological plausibility are main topics of these criteria. Whereby biological plausibility means that there are credible mechanisms which explain

how the noise exposure can contribute to the development of the illness. Furthermore it has to be demanded that the confidence intervals should be small for a save point-estimation. The causal interpretation of the association is finally supported by finding a dose effect relationship and comparable findings in independent studies.
The presented results fulfils not all but most of the causality-criteria. Change as well as bias can be excluded with high probability due to the sampling frame and due to the quality control within the study.
The evaluation of the data was carried out multiple with an extensive control variable set, taking into account the housing environment, regarding their influence on health. The large control variable set is, with regard to the variety of the examined diseases, not always to be considered complete. Furthermore, well known control variables are missing as one noise sensitivity and occupational noise exposure. Also the family history could not be taken into account. Air pollution, which has the same origin as traffic noise, could have a confounding impact on the results, but the effect could not differ essentially, because the risk pattern for traffic noise and neighbourhood noise does not differ dramatically. Altogether, the control process must be classified as sufficient according to comparable examinations.
The health effects of noise refer in all analyses to the cardiovascular system, the respiratory system, and the musculoskeletal system as well as on psychic disturbances. The biological plausibility for these effects is given due to experimental examinations. With central nervous processes, noise stress influences the neuro-endocrine system either directly or indirectly about emotional experience (disturbances, annoyance) or disturbed sleep. In this way noise exposures can lead to an inadequate and dangerous neuro-endocrine reaction pattern and finally to regulation diseases (see [Frankenhäuser et al. 1976]. Pathological changes can manifest themselves in the cardiovascular system (see [Babisch 2001]), in the respiratory system (see [Langewitz et al. 2003]) as well as in the musculoskeletal system (see [Eich 2003]) or can appear as psychic disturbances (see [Maschke et al. 2003]).

On the other hand pathological changes reduce more or less the mental well being and therefore may increase the susceptibility to noise. From this point of view the epidemiological association between annoyance and health-endpoints could be interpreted as caused by the diseases. For the association between sleep disturbances and health-endpoints it is nearly the same. Sleep could be disturbed by diseases, for example by bronchitis or asthma.

That well being as well as sleep could be influenced by individual state of health is well known, but the thesis that the associations in the LARES-study are essentially caused by the state of health is not very probable. Most of the examined diseases are heavily dependent on age, with a considerably higher occurrence among the elderly (with the exception of allergy). If the epidemiological associations are essentially caused by diseases, the frequency of noise induced annoyance as well as of noise induced sleep disturbance in the elderly people must be considerably higher than in adults. That is not the case for noise induced annoyance and noise induced sleep disturbances. The relative frequencies of noise induced annoyance as well as of noise induced sleep disturbance in elderly people are remarkably less than in adults. Therefore, we assume that the epidemiological associations are essentially caused by noise annoyance as well as by noise induced sleep disturbances, although also influenced by the effect of the individual state of health.

This assumption of a causal relation between noise induced annoyance and health-endpoints is supported by dose effect considerations. The relative risks for pathological changes in the cardiovascular system (hypertension, CV-symptoms) were clearly increased in adults at chronically strong annoyance (RR=3.0; 3.1), in comparison to adults indicated by moderate annoyance. At moderate annoyance the Relative Risks are no different than in the reference

group or only slightly increased (general neighbourhood noise, RR=1.3). This also applies for pathological changes in the respiratory system (Bronchitis, respiratory symptom), for arthritis and for depression.

To summarize, it can be concluded that the results of the LARES study confirm increased health risks at chronically strong noise annoyance as well as for noise induced sleep disturbances on an epidemiological level.

The health risks are dependent on the age groups. Few differences can be recognized within an age group regarding the pathogenesis mechanism of annoyance and sleep disturbances. At strong annoyance the risk pattern between general traffic noise and general neighbourhood noise are very similar within the age groups (see Table 2). With children the uncertainty of the annoyance rating is, however, to be taken into account (see chapter 0). The surprisingly high relative risks for neighbourhood noise partly can be explained by the high information content of neighbourhood noise.

If the risk pattern of noise induced sleep disturbances compared with the risk pattern of strong annoyance induced by noise (see Table 2), a good agreement is visible. In the group of elderly people a remarkable feature is highlighted. A significant increase of the risk of stroke is evident only at strong noise induced annoyance and only in elderly people.

Table 2: Significantly Odds Ratio for diseases calculated in the LARES-study

Significantly OR for diseases		Adults	Elderly	Children
general traffic noise strongly annoyed	Hypertension	1,588	----	----
	CV symptoms	1,545	----	(5,455)*
	Stroke	----	2,718	nc
	Asthma	----	----	----
	Bronchitis	1,861	----	2,624
	Resp. Sympt.	1,969	----	2,563
	Arthr. Sympt.	1,754	2,066	----
	Depression	2,229	----	nc
	SALSA	1,879	----	----
general neighbourhood noise strongly annoyed	Hypertension	1,706	----	nc
	CV symptoms	1,601	----	----
	Stroke	----	2,415	nc
	Asthma	----	----	----
	Bronchitis	1,907	----	3,453
	Resp. Sympt.	1,572	----	3,562
	Arthr. Sympt.	2,346	1,885	----
	Depression	1,78	1,989	nc
	SALSA	2,276	----	3,322
sleep been disturbed by noise	Hypertension	1,485	----	----
	CV symptoms	1,449	----	----
	Stroke	----	----	nc
	Asthma	----	2,019	----
	Bronchitis	1,455	----	3,674
	Resp. Sympt.	1,632	----	1,943
	Arthr. Sympt.	1,598	1,617	(7,308)*
	Depression	1,466	----	----
	SALSA	2,26	1,413	3,413

( )* very large confidence intervals
nc = not calculable

Regarding the different age groups pathological changes appear in adults both in the cardiovascular system, the respiratory system, the musculoskeletal system and in depression (see Table 2). Unlike this, with older people significantly increased risks exist only for the musculoskeletal system (arthritic symptoms) independent of the noise source. With strong annoyance, furthermore the risk is increased significantly for stroke among the elderly. The results of the LARES study do not confirm the thesis that older persons are subjects of an increased noise induced health risk.

A comparable result is published by Maschke [2004] for the Spandau Health-Survey (SHS). The SHS shows a stronger association between treatments of hypertension and the nightly noise level for adults less than 60 years in comparison with elderly people.

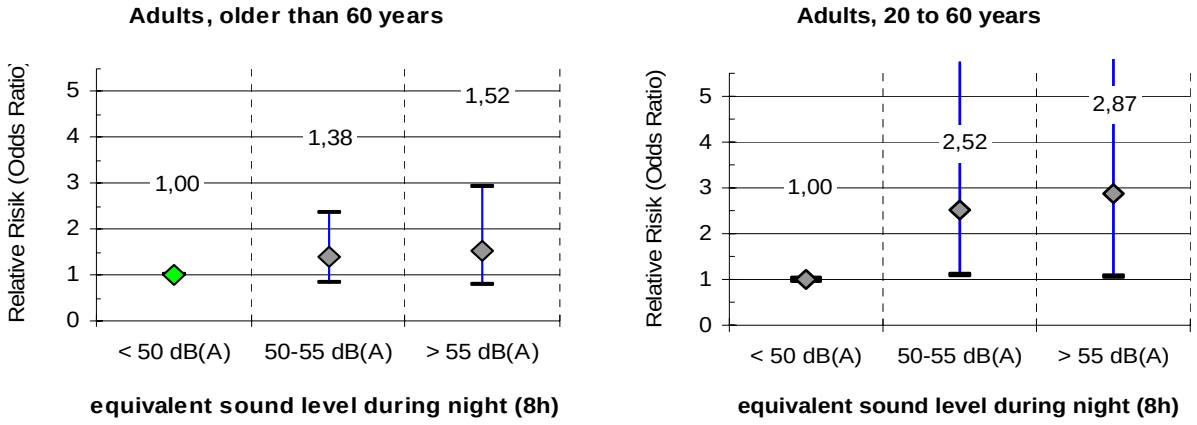

Figure 17: Statistical association between nightly road traffic noise and hypertension treatments in the 9th repetition cycle. Adjusted for "age", “sex”, "consumption of alcohol", "consumption of tobacco", "professional mobility", "sports", "body mass index", "social economic index", "loss of spouse", "hearing ability", "noise sensitivity" and "season of the medical examination".

With children the effects of noise is to be seen primarily in the respiratory system (see Table 2). Strongly annoyed children fall 2-3.7 times more in ill with respiratory diseases than non noise annoyed children. The same effect exists for noise disturbed sleep with approximately the same range of risk. In contrast, allergy, one of the most frequent illnesses of children, does not seem to respond to noise. According to the presented results, children have to be classified as particularly sensitive to noise with regard to the respiratory system.

Conclusions

The result confirms the thesis that for chronically strong annoyance a causal chain exists between the three steps health – strong annoyance – increased morbidity.

For adults with strong annoyance, significantly elevated relative risks exist both in the cardiovascular system, the respiratory system, and the musculoskeletal system as well as by depression. Elderly people with strong annoyance respond less than adults with the exception of stroke. With children the effects of noise is to be seen primarily in the respiratory system.

A further effect of noise is sleep disturbances. Sleep can be severely disturbed by noise. Acute sleep disturbances effect performance and in the long run health. For adults significantly elevated relative risks in the cardiovascular system, the respiratory system, and the musculoskeletal system as well as with depression exist with noise induced sleep disturbances. Many of these diseases increase with age and therefore in children only appear rarely. With children significantly elevated relative risks in the respiratory system as well as in migraines (self reported) are of great importance.

The association between noise induced sleep disturbances and morbidity are approximately in the same range as the consequences of noise induced strong annoyance. By noise induced sleep disturbances more people are effected (23.3%) than by noise induced strong annoyance (12.4% neighbourhood noise; 14.4% traffic noise). Therefore, particular attention must be paid to nightly environmental noise exposure.

Little attention was paid to neighbourhood noise till now and therefore pathological effects are considerably underestimated. The health effect of neighbourhood noise induced annoyance is approximately in the same range as the health effect of traffic noise induced annoyance. The results point out that it is necessary to improve the sound insulation in residential buildings.

The respiratory system also reacts to neighbourhood noise with increased relative risks. In contrast to traffic noise, with neighbourhood noise, air pollution cannot be responsible as an alternative reason for the increased health risks in the respiratory system. The noise has to be classified as an independent risk factor for the respiratory system.

Literature

Babisch, W.; Ising, H. (2001): Noise induced stress is a risk factor in cardiovascular disease. In: The 2001 International Congress Noise Control Engineering. The Hague, The Netherlands

Eich, W. (2003): Chronische Polyarthritis and Fibromyalgie (Chronic polyarthritis and Fibromyalgie). In: Adler, RH.; Herrmann, JM.; Köhle, K.; Langewitz, W.; Schonecke, OW.; Uexküll von, T.; Wesiak, W. (eds): Uexküll Psychosomatische Medizin- Modelle ärztlichen Handelns. 6. Auflage. Urban & Fischer, München, Jena, 941- 946

Frankenhäuser, M.; Lundberg, U. (1976): Psychological reactions to noise as modified by personal control. Reports from the Department of Psychology, U. Stockholm Vol. 471

Langewitz, W.; Solèr, M. (2003): Asthma bronchiale (Asthma bronchial). In: Adler, RH.; Herrmann, JM.; Köhle, K.; Langewitz, W.; Schonecke, OW.; Uexküll von, T.; Wesiak, W. (eds): Uexküll Psychosomatische Medizin- Modelle ärztlichen Handelns. 6. Auflage. Urban & Fischer, München, Jena, 891- 907

Maschke, C.; Wolf, U.; Leitmann, T. (2003): Epidemiologische Untersuchungen zum Einfluss von Lärmstress auf das Immunsystem und die Entstehung von Arteriosklerose (Epidemiological examinations to the influence of noise stress on the immune system and the emergence of arteriosclerosis). WaBoLu-Hefte 01/03 Umweltbundesamt, Berlin

Maschke, C. (2004): Health Effects of nocturnal traffic noise – sound level at subjects´ home versus self-reported sleep disturbances. In: 30. Jahrestagung der Deutschen Gesellschaft für Akustik (DAGA) (Proceedings of the 30th Annual Acoustical Congress of the German Society of Acoustics), Strasbourg, France (in press)