ASSOCIATION BETWEEN ENVIRONMENTAL NOISE ANNOYANCE AND SOUND LEVEL. FIRST RESULTS OF THE "NAROMI" STUDY (NOISE AND RISK OF MYOCARDIAL INFARCTION)

PACS REFERENCE: 43.50.QP

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ABSTRACT

To determine the potential risk of noise for the incidence of myocardial infarction (MI), patients with confirmed diagnosis of MI were enrolled. Controls were matched according to gender, age, and hospital. A total of 4115 patients were included in the study. Standardized interviews were conducted including the assessment of noise annoyance from various environmental sources. The traffic noise levels were determined from standardized sound maps. To account for multiple exposures, different concepts of summation of annoyance are proposed (sum score, maximum score, factor score). Preliminary analyses revealed significant associations particularly regarding annoyance due to road traffic noise, aircraft noise and construction works. The effects were more pronounced in females than in males.

INTRODUCTION

The NaRoMI-Study ("Noise And Risk Of Myocardial Infarction") is a new epidemiological case-control study on the impact of environmental noise and occupational noise on the incidence of acute myocardial infarction (MI). Previous studies using similar methods suggested an increased risk of MI in subjects exposed to high noise [1,7]. The purpose of the present paper is to evaluate the inter-relationships between objective (sound level) and subjective variables (annoyance) of noise exposures and their impact on the health outcome [5]. The focus here is on methodological issues and model assumptions.

METHODS

Consecutive patients admitted to 32 major hospitals in Berlin with confirmed diagnosis of MI were enrolled from 1998 to 2001. Their objective (sound level) and subjective (annoyance) noise exposure was assessed using noise maps of the city authorities and standardised questionnaires. The noise exposure of the cases was compared with that of control patients from the trauma and general surgery departments of the same hospitals (diagnoses supposedly not related to the exposure). Cases and controls were matched according to age, gender and hospital (case:control ratio for men 1:1, for women 1:2). Statistical calculations were carried out using the software package SPSS 9.0.

Among the total of 4115 study participants (age: 20-69 yrs) were 74% males (mean age 56.1 yrs, SD = 8.5) and 26% females (mean age 57.7 yrs, SD = 8.7). All of the following calculations refer to a reduced study sample size of N=4006, where non-missing values were available for all variables considered, to make all results directly comparable.

The traffic noise levels (average A-weighted sound pressure level) as determined from noise maps were calculated with reference to the most affected facades of the dwellings ("immission level") for day (6-22 h) and night (22-6 h). The noise maps were established in accordance with German standards on the basis of traffic counts (RLS90, Schall09). The sound levels ranged from ≤60 to 79 dB(A) during day and ≤50 to 73 dB(A) during night. All major streets with approx. >6000 vehicles per day or tram lines (no bonus considered in the analyses) were explicitly assessed by the traffic authorities. Streets with less traffic volume were primarily categorised as "quiet" (approx. <60 dB(A), not measured). This applied to 59% of the study sample and reflected the common noise distribution in a random sample of addresses [17]. However some of the measured streets were also found to have lower day/night immission levels i.e. below 60/50 dB(A). A distinction was made in the analyses between the two groups. To account for other transportation noise, dichotomous variables were assessed, so that subjects who lived within the 60 dB(A) contours ("q=3") around airports or near railway lines were indicated.

Personal interviews were carried out in the hospitals. Environmental noise annoyance was determined using 5-point scales of which the anchor points were verbalised ("Considering the last years, how much were you disturbed by x-noise at home"; 1= not disturbed at all, 5 = very disturbed) [6]. Eight noise sources around and in the subject's homes were considered. These included: road traffic noise, aircraft noise, railway noise (including tram), noise from construction works, commercial noise (including noise from industries), impact noise (from neighbours), other indoor noises and other outdoor noises. The items were administered in two blocks referring to disturbances during the day and the night. The German version of Weinstein's 21-item scale was applied to assess (subjective) noise sensitivity [19]. Mean values were calculated (0 = lowest, 5 = highest).

RESULTS

Table 1 gives the distribution of day and night sound levels. *Table 2* gives distributions of noise annoyances due to different sources. Analyses revealed that noise sensitivity clearly showed a normal distribution (no figure). The distributions of sound levels were in accordance with other investigations carried out in Germany [17]. Approx. 16% of the subject's homes were exposed to sound levels of more than 65 dB(A) during day, which has been discussed as a threshold of an increase in risk of cardiovascular disorders [2]. Most annoyance reactions were due to road traffic noise. The number of subjects "highly" annoyed (categories 4+5) during day and night were 13.5% and 7.6%, respectively. These numbers are slightly lower than the average figures for Germany [17].

Table 1: Distribution of sound levels [%]

Period	Sound level category [dB(A)]				
Day	60 not measured	60	61-65	66-70	>70

	59.0	13.4	11.6	10.5	5.6	
Night	50 not measured	50	51-55	56-60	61-65	>65
	59.0	6.1	11.4	10.8	9.4	3.4

Table 2: Distribution of noise annoyance [%]

Noise source	Annoyance category [5-point scale]				
	1	2	3	4	5
Day					
Road traffic noise	45.4	24.3	16.8	7.5	6.0
Aircraft noise	63.3	20.7	8.5	3.6	3.9
Railway noise	83.8	9.2	4.0	1.8	1.2
Construction noise	73.1	9.7	7.2	5.1	4.9
Commercial noise	90.1	4.5	3.0	1.5	0.9
Outdoor noise (other)	68.7	17.9	6.7	3.7	3.1
Impact noise	73.7	12.8	6.6	4.0	2.9
Indoor noise (other)	71.9	15.3	6.7	3.3	2.7
Night					
Road traffic noise	73.4	11.6	7.4	4.1	3.5
Aircraft noise	88.2	6.7	2.5	1.4	1.1
Railway noise	91.0	5.0	2.4	1.0	0.6
Construction noise	96.9	1.2	0.8	0.7	0.4
Commercial noise	95.2	1.7	1.1	1.1	0.8
Outdoor noise (other)	84.3	8.3	3.9	1.9	1.6
Impact noise	88.5	5.5	3.0	1.5	1.5
Indoor noise (other)	83.7	9.4	3.8	1.8	1.3

The associations between sound level (road traffic) and noise annoyances are given in *Table 3* (mean value of the annoyance ratings in each noise category). Non-parametric tests ("Kruskal-Wallis") and analyses of variance (F-Test, "Anova") were carried out, to test for group differences (sound level categories) and linear trends (continuous sound level readings). As expected, of the sources other than road traffic noise, aircraft noise, indoor noise and other outdoor noise did not show any systematic association with the traffic noise level. However, significant statistical tests revealed that noise annoyances from railways, construction works, commercial activities and industry, and impact noise increased with increasing sound level. The finding regarding impact noise is puzzling. The other findings, however, may be explained by the fact that these noises are partly determined by traffic-related activities (the traffic noise level includes sound from trams, commercial noise includes noise from transportation, e.g. trucks), or come from the streets (e.g., road works).

As far as the relationship of a trend between traffic noise level and annoyance due to road traffic is concerned, the mean annoyance in the primarily "quiet" areas (no measurements taken) was lower than that in the quietest areas, where measurements of the sound level were actually taken (60/ 50 dB(A)). This supports the basic assumption that the sound level in the non-measured areas was as to be expected, lowest. Sound level and annoyance due to traffic noise usually show a monotonically increasing relationship [11]. Regarding annoyance from other noise sources, the two lowest categories did not dffer substantially. However, annoyance due to aircraft noise was highest in the group least exposed to road traffic noise. This may be due to the fact that particularly suburban areas were affected the major Berlin airport.

The association between noise sensitivity and sound level is also given in *Table 3*. The parametric test for a linear trend revealed an inverse association of decreasing noise sensitivity with increasing sound level. This may be due to self-selection, in the highest exposure group. Noise sensitive subjects may have tended to move out of these areas. However, the non-parametric test for group differences did not quite reach the statistical significance.

Table 3: Association between sound level and noise annoyance [mean category score]

Noise source		Sound level category [dB(A)]					Significance[1)] Group/Trend
Day	60 not measured	60	61-65	66-70	>70		
Road	1.79	2.04	2.32	2.78	2.72		*** / ***
Air	1.68	1.58	1.61	1.59	1.59		* / n.s.
Rail	1.25	1.22	1.31	1.37	1.46		*** / ***
Construction	1.55	1.54	1.73	1.70	1.58		** / n.s.
Commercial	1.16	1.22	1.16	1.29	1.29		*** / ***
Outdoor (other)	1.55	1.54	1.56	1.50	1.57		n.s./ n.s.
Impact	1.46	1.51	1.51	1.53	1.74		** / ***
Indoor (other)	1.46	1.57	1.57	1.54	1.51		** / n.s.
Noise sensitivity	2.86	2.81	2.85	2.82	2.75		n.s./ *
Night	50 not measured	50	51-55	56-60	61-65	>65	
Road	1.37	1.44	1.62	1.72	2.07	1.82	*** / ***
Air	1.22	1.14	1.22	1.17	1.16	1.21	n.s./ n.s.
Rail	1.14	1.09	1.19	1.16	1.19	1.27	* / **
Construction	1.06	1.01	1.06	1.07	1.15	1.04	*** / **
Commercial	1.09	1.12	1.12	1.09	1.14	1.22	n.s./ *
Outdoor (other)	1.27	1.29	1.31	1.30	1.26	1.42	n.s./ n.s.
Impact	1.19	1.20	1.27	1.22	1.31	1.29	* / **
Indoor (other)	1.26	1.27	1.32	1.28	1.35	1.30	n.s./ n.s.
Noise sensitivity	2.86	2.80	2.84	2.85	2.82	2.67	n.s./ *

[1)] Group: Kruskal-Wallis-Test, Trend: F-Test (Anova); * p<0.05, **p<0.01, ***p<0.001, n.s.=not significant; (2-tailed)

Correlation analyses (Non-parametric Spearman test) give some deeper insight into the inter-relationships between the exposure variables. Corresponding with the results of the analysis of variance, the correlation coefficients between the road traffic noise level and traffic noise annoyance was r=+0.27 (day) and r=+0.20 (night). The smaller coefficient regarding the night can be explained by the fact that bedrooms might not have been situated on the noisiest side of the buildings. The correlation coefficients of any of the other noise annoyances and traffic noise level ranged between r=-0.04 (aircraft noise) and r=+0.07 (railway noise). The sound level-related variables identifying areas exposed to aircraft noise (day: r=+0.36; night: r=+0.24) and railway noise (day: r=+0.24; night: r=+0.13) showed significant associations with the corresponding source-specific annoyance variables. Only minor correlations were found between these variables with other sources of noise annoyance (the highest was |r|=0.06). All these results confirm the validity of the noise assessment in our study.

Inter-correlations between annoyance variables revealed correlation coefficients between road traffic noise (the primary focus of the present analyses) and other environmental noise sources ranging between r=+0.16 and r=+0.24 (day) and r=+0.13 and r=+0.27 (night). This may partly be an effect of the use of test batteries, where the subjects adjust their individual rating levels to the answer given in the first item of the list. The first item in the list could play a crucial role in this respect, being a kind of reference for all the following ratings in making answers consistent relative to one another within subjects. The issue may be relevant when sum scores are calculated and then compared between subjects, particularly when the first item of the list is relevant for some subjects but not for others. Noise sensitivity was associated with all annoyance items in the study sample and correlation coefficients ranged from r=+0.09 (rail) to r=+0.27 (road).

CONCLUSIONS

The results of the relationships between sound level and annoyance give confidence in the validity of the assessment of noise in the NaRoMi-Study. The road traffic noise level was taken from noise maps of the City of Berlin. A monotone relationship between the sound level outdoors and the annoyance due to traffic noise was found across all sound level categories, as usually found in social surveys [11]. Total annoyance, in principle, may not be determined by the sum of annoyance ratings of single noise sources due to masking and interaction [4,8,10,13]. This holds also true for the combination of day and night annoyances [18]. On the other hand, source-specific annoyance ratings often tend to be higher in the presence of other noise sources [14]. Regarding possible health effects the whole issue was not studied systematically before. To account for multiple sources of noise annoyance in the logistic regression models on environmental determinants of MI incidence the following four concepts are suggested.

Firstly, all annoyance items can be introduced simultaneously. The advantage is that source-specific interpretations are possible. All variables would then contest with each other in the prediction of the health effect. Each variable acts as a possible confounder for the other. The model would be adequate in this respect, since we know that different noise sources cause different annoyance reactions for the same sound level. It would be interesting to see whether different noise sources cause different health effects for the same level of annoyance. Due to collinear effects between day and night annoyances, it may not be possible to have both source-specific items in the model at the same time. However, day and night annoyances referring to the same source can be combined to one factor before being introduced into the model together with the other annoyance factors.

Secondly, the sum-score of all day annoyances, night annoyances or total annoyances can be calculated. The advantage of this concept is that the statistical models rely on less degree of freedom than the models including all single annoyance items. On the other hand, serious annoyances may be "played down" by the averaging procedure when other noise sources are not relevant for the individual (For example, 8 noise sources considered: "Are ratings of 1x5 + 7x1 the same as 5x2 + 2x1 with regard to health effects?").

Thirdly, the maximum annoyance (day, night, or in total) can be calculated as a determinant of possible health effects. The idea behind this is, that it would not matter what the cause of the annoyance is. If someone is annoyed by at least one source of noise, it may indicate psychological distress that may affect physiological health. Annoyance in this concept is viewed as a state of expressed discomfort - regardless of what type of noise. However, the max-score concept would not consider the impact of combined noise sources on the health outcome.

A fourth concept, which is similar to the second, is to treat factor scores of a rotated factor analyses as predictors in the model. The factor scores would account for inter-relations between the single annoyance variables before entered into the model. The effects of the orthogonal variables would be primarily independent of one another. This concept may be most effective for hypothesis testing because the new variables (factors) consider the correlations between the single variables within subjects, thus accounting for the differences of individual rating niveaus. However, the factors may be difficult to interpret in terms of their content and their numerical value and therefore may be less informative for noise policy.

Subjective noise sensitivity was shown to be related to personality factors such as depressed mood, negative affectivity, neuroticism, or vulnerability to stressors in general, that may affect health [3,9,12,15,16]. When it is a predictor of MI incidence and correlated with noise annoyance, there may be some conceptional concern about having both simultaneously in the model. This is even more an issue if all three - sound level, annoyance and noise sensitivity - are treated together in one model. If prediction is the key issue of the study, this would be a minor problem. However, if hypothesis testing is the main issue of a study, the effects of partialling out these variables may be difficult to interpret. (For example, what would be the meaning of the residual of the annoyance variable, if its partial components of sound level and noise sensitivity are "subtracted"? Would it still reflect the annoyance assessed in social surveys, of which we want to know how it is related to health?) The main analyses of the NaRoMi study on the association between noise exposure and incidence of myocardial infarction are in progress and will be available in the near future.

Detailed results with regard to the different concepts discussed above will be presented at the EAA conference.

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