The NaRoMI-Studie

(Noise and Risk of Myocardial Infarction)

Executive Summary

- Traffic Noise -

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(Noise and Risk of Myocardial Infarction)

Executive summary – traffic noise

It was the objective of the research project „Noise and Risk of Myocardial Infarction" to study the quantitative impact of the exposure to chronic road traffic noise occupational noise on the incidence of acute myocardial infarction (MI). The research was funded by the Federal Environmental Agency within the framework of the German Environmental Research Plan ("Ufoplan", ref. 29761003) of the Ministry for the Environment, Nature Conservation and Nuclear Safety, and the Institute for Occupational Safety and Health, who were responsible for the exposure assessment of the study population in their fields. The Institute of Social Medicine, Epidemiology and Health Economics belonging to Charité Hospital, Humboldt University of Berlin Germany was the principle investigator and responsible for the study design, the field work and the data management.

Due to concerns about inadequate statistical treatment of the traffic noise data in the report of the principle investigator, the Federal Environmental Agency carried out its own and additional analyses, which are given here. Any differences in the analyses are not concerned with the database as such. All investigators refer to the same statistical models and effect estimates of confounding factors. The disagreement, however, is concerned with the decision about the appropriate reference group to be considered for the assessment of the MI-risk of noise-exposed subjects and the interpretation of the study results.

Background

Epidemiological studies on the relationship between transportation noise and ischaemic heart disease (IHD) suggest a higher risk of myocardial infarction in subjects exposed to high levels of traffic noise. Although the findings in these studies seem to be reasonably consistent, individual study results often lack significance due to the low statistical power of the study. The existing data on the relationship between road traffic noise and IHD suggest an average A-weighted sound pressure level of 65-70 dB(A) during the day as a possible threshold of effect [5,58]. A previous population-based case-control study carried out in the former western part of the city of Berlin, revealed an estimate of the relative risk for myocardial infarction of OR=1.32 (95% confidence interval: 0.89-1,96) in males, who had lived for at least 15 years in streets with average A-weighted sound levels of more than 70 dB(A) during the day compared to subjects who lived in streets with sound levels up to 60 dB(A) [9]. The NaRoMI (Noise and Risk of Myocardial Infarction) study is a replica of the previous one, using the same test hypothesis [11]. It takes a larger sample size and uses improved methods of exposure assessment, and a larger set of potentially confounding factors are taken into account in the statistical analyses. It is a hospital-based case-control study covering the entire city of Berlin.

Methods

To determine the potential risk of noise for the incidence of myocardial infarction (MI), patients consecutively admitted to 32 major hospitals in Berlin with confirmed diagnosis of acute MI and reanimated survivors of sudden cardiac death were enrolled over a prospective period of 3 years from 1998 to 2001. Hospital controls were matched according to gender, age (5 yr categories) and hospital. Because of the lower incidence rate of MI in women, a case:control ratio of 1:1 for men and 1:2 for women was taken, so increasing the statistical power. It was presumed that the diagnoses of control patients admitted to the same hospitals for accidents or surgical procedures were not related with noise.

The total number of 4115 study participants (age: 20-69 yrs, response rate 86%) was made up of 3054 males (mean age 56.1 yrs, SD = 8.5) and 1061 females (mean age 57.7 yrs, SD = 8.7). Standardized interviews were conducted during the hospital stay, after the subjects were moved from the intensive care wards to the peripheral wards, to assess information about the home environment, socio-demographic and potentially confounding factors. These included: family history of MI ("yes/no"), smoking ("present smoker/former smoker/non-smoker"), school educational level ("below A-level/A-level"), marital status ("single/with partner"), employment status ("unemployed/not in work for other reasons/employed"), working hours (">40 hr per week/≤40 hr"), shift work ("yes/no"), second job or activity ("yes/no") and Weinstein noise sensitivity (continuous scale ranging from 1 to 6). Clinical diagnoses regarding the prevalence of diabetes mellitus ("yes/no"), hypertension ("yes/no"), hyperlipemia ("yes/no") and body mass index ("no data/25-<30/≥30/<25 kg/m^2") were taken from the records of the clinics. To account for possible confounding, adjustments in the statistical models were made with respect to the categorizations given in brackets (the last of each serving as a reference). Due to possible incomplete assessment in controls, hyperlipemia was considered only in sensitivity analyses where it did not affect the results considerably.

The objective traffic noise exposure (sound level) of the subjects was assessed using noise maps of the city authorities and standardized questionnaires. The traffic noise levels (12 months average A-weighted sound pressure levels) as determined from noise maps were calculated with reference to the most affected facades of the dwellings for day (6-22 h) and night (22-6 h) [67]. The noise maps were established in accordance with German standards for road and rail traffic (RLS90, Schall03). All main roads with more than approx. 6000 vehicles per day were assessed by the traffic authorities, and exact sound immission levels were calculated for more than 6300 street segments (parts between junctions) [66,68]. Streets with lower traffic volume (side streets) were categorised as "quiet". No exact sound levels can be given for these streets. However, the cut-off criterion of traffic volume refers to average A-weighted sound levels during the day (L_{6-22hr}) of approx. 60 dB(A) and approx. 50 dB(A) during the night (L_{22-6hr}) at a distance of 25 m from the streets (max. speed 50 km/h, 5% heavy vehicles). The maximum allowed speed in 85% of all the side streets was 30 km/h and 50 km/h in all other (exception: motorways 80-100 km/h) [66]. The group of subjects living in side streets served as the reference group in the main statistical analyses, which was in accordance with the a priori test hypothesis and the previous noise studies. The procedure was validated using data of 4 (out of 12) Berlin District Councils that assessed the noise levels in all the side streets of their parts of the city (more than 5800 street segments).

All individuals' houses were categorized in 5 dB(A)-categories according to the sound levels given in the traffic noise map. In the first step this was done with reference to the home address (in most cases the street closest to the buildings). In the second step, all addresses were checked for noise from streets other than the home address. Using high-resolution GIS information (digitalized topographic maps, scale 1:500), the distances to all streets of which exact sound levels were given in the noise map were measured for each house where subjects lived. If the subjects' houses were within relevant distances to busy streets (i.e. according to the physical rules of sound propagation and attenuation), and not completely shielded by sound barriers from other houses, then exact sound levels were calculated with respect to the facades of the subjects' houses. When this sound level was higher than the one for the street of the address, the subjects were re-allocated into the respective sound level category. Otherwise, the subjects remained in their initial category. All noise calculations were made separately with respect to the front of the house (facing the street of the address) and to the back of the house. The years of residence at the present address were assessed to account for exposure misclassification due to long induction periods of the disease and possible effect modification.

To account for transportation noise other than from the streets, dichotomous variables were assessed, so that subjects who lived within the 60 dB(A) contours around airports or near railway lines could be noted. The calculations were made according to the German aircraft noise regulations (exception: equivalence parameter "q=3" was considered), the train noise module of the Berlin noise map, and the measured distance of houses from railway lines. The two variables were considered as potential confounders in the statistical analyses. The 10 years work noise exposure (sound level) was determined according to ISO 9921/1 assessing vocal effort for speech communication and according to catalogues for workplaces and machines, allowing for the use of ear protection. More details will be given elsewhere. For the traffic noise related analyses, one indicator of occupational noise exposure ("no data/no job/≤55/>55-70/>70-85/>85 dB(A), corrected for use of ear protection") was used to control for possible confounding. Replacing it with other work noise indicators did not considerably affect the results of the traffic noise level-related analyses.

The subjective noise exposure (annoyance) was assessed using a standardized questionnaire. Personal interviews were carried out in the hospitals. Environmental noise annoyance was determined using a 5-point scale of which the anchor points were verbalized ("Considering the last years, how much were you disturbed by x-noise at home; 1= not disturbed at all, 5 = very disturbed?"). Eight noise sources around and in the subject's homes were considered. These included: road traffic noise, aircraft noise, railway noise (excluding tram), noise from construction works, commercial noise (including noise from industries), impact noise, indoor noise and other outdoor noises. The items were presented in two lists referring to disturbances during the day and the night. To control for annoyance from occupational noise, an indicator variable was used ("no data/no job during past 10 years/low/fairly low/fairly high/high annoyance"). It was based on information, which was taken from the noise questionnaire referring to noise from the outside of the working room, from the subject's own machines or appliances and noise from machines or appliances used by colleagues (sum score of annoyance weighted by duration of employment [62]).

Conditional logistic regression analyses (LogXAct, version 4.02) were carried out to estimate relative risks (matched analyses), and to adjust the results for a set of potentially confounding factors. Non-parametric regression coefficients (SPSS, version 9.0) were calculated to assess associations between the determinants of noise exposure. Associations between noise level and MI incidence were analyzed in the total sample and a sub-sample of subjects that had been living at least for 10 years in their present homes, to account for chronic noise stress conditions and long induction periods of the disease under study. The decision was made on the basis of the distribution of the residence time on the one hand and pragmatic grounds of sample size and statistical power on the other. To ensure that effect estimates obtained from the sub-sample were stable, other criteria were also applied (e. g., 15 years). Two methods were applied: stratification of results by excluding all subjects who had not been living for 10 years at their present address (restriction) and multivariate modelling of the two strata (<10 years vs. ≥10 years). Both methods have advantages and disadvantages with respect to the possible introduction of bias [29,35,60]. For example, due to the matched-pair type of analysis a number of discordant ("informative") strata will be lost by restriction. On the other hand, regression modelling is a complex process that makes assumptions about the true associations between variables (e. g. linearity) in the source population, that can easily be violated.

Results

Table 1 shows adjusted risk estimates (odds ratio an 95%-confidence intervals) for the relationships between control variables and the incidence of myocardial infarction as derived from the multiple logistic models, where only the factors given in the table were considered (reference categories are given in the methods paragraph). Established biological and non-biological risk factors (diabetes mellitus, hypertension, family history of MI, smoking) were significantly associated with MI incidence showing odds ratios between 1.7 and 3.1 and were within the range of usual findings in epidemiological studies [16,22,26,51-53,79,80]. Due to incomplete assessment of hyperlipemia in the controls (hospital records) the odds ratios of 5.5

and 4.5 in males and females tend to be too high. However, the inclusion or exclusion of this variable did not considerably affect the estimates that were obtained for any of the noise-related factors in the later analyses.

Table 1: Association between control variables and MI-incidence (multivariate model)

Factor	Relative MI risk [OR, 95% CI]	
	Males (N=3054)	Females (N=1061)
Diabetes mellitus	1,84 (1,43-2,38)	3,00 (1,95-4,62)
Hypertension	2,24 (1,87-2,70)	1,99 (1,45-2,74)
Family history of MI	2,11 (1,73-2,57)	2,00 (1,45-2,76)
Current smoker	2,69 (2,11-3,43)	3,85 (2,64-5,61)
Former smoker	1,80 (1,41-2,30)	1,97 (1,31-2,96)
BMI 25-<30 kg/m^2	1,22 (1,02-1,46)	1,14 (0,80-1,62)
BMI ≥30 kg/m^2	0,89 (0,70-1,13)	1,42 (0,95-2,13)
BMI unknown	5,42 (1,93-15,2)	1,56 (0,23-10,5)
>40 h/week working hours	1,14 (0,97-1,35)	1,02 (0,71-1,46)
Being unemployed	0,74 (0,57-0,97)	1,09 (0,60-1,96)
Being retired	0,57 (0,45-0,72)	0,52 (0,33-0,83)
Living without partner	0,55 (0,45-0,67)	0,60 (0,44-0,83)
Second job	1,11 (0,89-1,37)	1,23 (0,81-1,85)
Shift work	1,05 (0,87-1,27)	1,08 (0,71-1,65)
Lower education	1,11 (0,91-1,36)	1,68 (1,07-2,62)
Noise sensitivity (per unit of a 6-point scale)	1,14 (1,01-1,29)	1,05 (0,85-1,30)
High blood lipids *	5.52 (4.35-7.00)	4.45 (3.06-6.47)

** When added to the model*

Table 2 gives the distribution of traffic noise levels during the day in the total sample. It refers to the highest average sound level measured during the daytime at any outside wall of the subjects' houses. Since non-categorized day and night sound levels were highly correlated (r = 0.98, mean difference 7.3 dB(A)), only the results referring to the sound level during the day are given here. In future analyses, a distinction will be made between the exposure of the living room (during the day) and the bedroom (during the night). Approx. 16% of the subjects' houses were exposed to sound levels of more than 65 dB(A) during the day. 69% of the subjects lived for at least 10 years at their present address.

The analyses of sound level data referring to the complete network of side streets of two inner and two outer Berlin districts revealed that 51% and 71%, respectively, of sound levels during the day were less or equal to 55 dB(A). 33% and 20%, respectively were between >55 and 60 dB(A), and 16% and 9%, respectively, were higher than 60 dB(A).

Table 2 also gives (for all the control variables mentioned above) the adjusted estimates of the relative risk (odds ratios) of myocardial infarction (MI) and 95%-confidence intervals (95% CI) for males and females in each traffic noise category (main analyses, a priori hypothesis). A slight increase in risk was found in males with increasing sound level in the total sample. The relative risk of OR=1.27 (95% CI: 0.88-1.84, p=0.200) found for men in the highest noise category (>70 dB(A)) compared to the lowest (≤60 dB(A)) was not significant. When the upper two noise categories were combined, the odds ratio for male subjects that lived in streets with sound levels during the day of more than 65 dB(A) was OR=1.18 (95%-CI: 0.93-1.49; p=0.171). In females the opposite tendency of a trend was found. The relative risk for those in the highest category of OR=0.66 (95% CI: 0.32-1.35) was also not significant (p=0.254).

In the sub-sample of subjects that lived for at least 10 years at their present address a stronger monotonous increase in risk was found in males across noise categories. The odds ratio for males in the highest noise category was OR=1.81 (95% CI: 1.02-3.21, p=0,043), which was significant. When the upper two noise categories were combined, the odds ratio for male subjects that lived in streets with sound levels during the day of more than 65 dB(A) was OR=1.45 (95%-CI: 1.03-2.05; p=0.034). The result was similar, when 15 years of residence was considered, but not significant due to the smaller sample size. Because the statistical model of the sub-sample did not converge for females when all control variables were considered (due to the smaller sample size), reduced models were calculated for females and males (for comparison) only including the classical risk factors. No noise effect was found for females, and the tendency of a decrease in risk as found in the total sample disappeared.

To assess the effect modifying impact of residence time using the modelling approach, a new variable was created which consisted of the following factor levels: ≤60 dB(A)/<10 years, ≤60 dB(A)/≥10 years, >60-65 dB(A)/<10 years, >60-65 dB(A)/≥10 years, >65-70 dB(A)/<10 years, >65-70 dB(A)/≥10 years, >70 dB(A)/<10 Jahre and >70 dB(A)/≥10 years („counterfactual approach" [60]). The analyses revealed no differences in risk between subjects of the lowest traffic noise groups regardless of the residence time (males: OR=1.01, females: OR=0.97). Therefore these groups were merged to one reference group. Table 3 shows the results of the analyses. None of the odds ratios for subjects in any of the traffic noise groups was significant. However, some characteristics can be seen. The decreasing trend of MI-risk across noise categories in females was more pronounced in females with short residence time than in females with long residence time. In males - although less pronounced than in the stratified analyses - effect modification was found in a way that the increase in risk across noise categories was stronger in males with long residence time than in males with short residence time. Since the men of the traffic noise categories >65-70 dB(A) and >70 dB(A) were equally at risk (OR=1.33 and 1.34, respectively), these categories were combined to increase the statistical power. The odds ratio of OR=1.33 (95%-CI: 1.00-1.76) for male subjects that lived in streets with sound levels during the day of more than 65 dB(A) was significant (p=0.046).

Table 2: Association between traffic noise level and MI-incidence, stratified with respect to residence time (main analyses)

Sound level, day [dB(A)] Total sample Sub-sample Relative MI risk [OR, 95% CI]	≤60 N=2990 (72.6%) n=2076	>60-65 N=472 (11.5%) n=333	>65-70 N=430 (10.4%) n=297	>70 N=223 (5.3%) n=148
Females, total sample	1	1.14 (0.70-1.85)	0.93 (0.57-1.52)	0.66 (0.32-1.35)
Males, total sample	1	1.01 (0.77-1.31)	1.13 (0.86-1.49)	1.27 (0.88-1.84)
Males, sub-sample ≥10 years of residence	1	1.17 (0.81-1.69)	1.31 (0.88-1.97)	1.81 (1.02-3.21)
* Females, sub-sample ≥10 years of residence	1	1.04 (0.55-1.97)	1.11 (0.62-1.98)	0.90 (0.39-2.07)
* Males, sub-sample ≥10 years of residence	1	1.12 (0.79-1.57)	1.18 (0.81-1.74)	1.65 (0.96-2.83)

* Model-adjusted only for diabetes mellitus, hypertension, family history of MI, smoking

Table 3: Association between traffic noise level and MI-incidence, model-adjusted with respect to residence time (main analyses)

Sound level, day [dB(A)] Relative MI-risk [OR, 95%-CI]	≤60	>60-65	>65-70	>70
Males <10 years of residence	1	0.94 (0.59-1.49)	0.84 (0.53-1.32)	1.16 (0.62-2.19)
Males ≥10 years of residence		1.06 (0.77-1.44)	1.33 (0.94-1.87)	1.34 (0.85-2.09)
Females <10 years of residence	1	*2.00* *(0.89-4.50)*	0.82 (0.34-1.98)	0.42 (0.11-1.59)
Females ≥10 years of residence		0.87 (0.49-1.56)	0.98 (0.56-1.72)	0.77 (0.33-1.79)

A puzzling result was found while carrying out the statistical analyses (a posteriori testing). Within the reference group two subgroups were identified. Reference subgroup 1 ("busy street not relevant") consisted of subjects who lived in side streets, which were not in relevant distance to main roads, or were completely shielded by sound barriers from these streets. No exact sound levels below the cut-off of $L_{Day} \leq 60$ dB(A) were given here. Reference subgroup 2 ("busy street relevant") consisted of subjects who also lived in side streets but in relevant distances to main roads so that sound levels could have been higher, but exact sound level calculations with respect to these main roads revealed that $L_{Day} \leq 60$ dB(A) was assured. Table 4 gives the odds ratios of MI incidence for the total sample with reference to subgroup 1 (sub-analyses). Surprisingly, a significantly lower MI risk was found in both sexes in sub-group 2.

Table 4: Association between traffic noise level and MI-incidence, stratified with respect to residence time (sub-analyses)

Sound level, day [dB(A)] Total sample Sub-sample Relative MI risk [OR, 95% CI]	≤60 subgroup 1 + N=2437 n=1698	≤60 subgroup 2 ++ N=553 n=378	>60-65 N=472 n=333	>65-70 N=430 n=297	>70 N=223 n=148
Females	1	0.45 (0.27-0.76)	1.03 (0.63-1.68)	0.83 (0.51-1.37)	0.58 (0.28-1.20)
Males	1	0.67 (0.52-0.85)	0.94 (0.72-1.23)	1.03 (0.77-1.37)	1.16 (0.80-1.69)
* Females, sub-sample ≥10 years of residence	1	0.56 (0.28-1.10)	1.00 (0.53-1.90)	1.01 (0.55-1.83)	0.81 (0.35-1.87)
Males, sub-sample ≥10 years of residence	1	0.74 (0.53-1.05)	1.12 (0.77-1.61)	1.21 (0.80-1.84)	1.67 (0.93-3.00)

* Model-adjusted only for diabetes mellitus, hypertension, family history of MI, smoking
+ Subjects' houses not in relevant distances to a main road or completely shielded by sound barriers
++ Subjects' houses in relevant distances to a main road but calculations of the sound level revealed that 60 dB(A) was not exceeded

Table 5 shows the associations between noise annoyance and MI incidence. Separate models were calculated with respect to disturbances during the day and night. To handle all the eight annoyance variables simultaneously, they were treated as continuous variables in the models. The odds ratios give an estimate of the relative risk per unit of the 5-point scale. All sound level-related variables were excluded from the analyses as well as noise sensitivity for reasons of collinearity between variables. However, annoyance from noise at work was considered.

Road traffic noise annoyance at night in males (OR=1.10; 95% CI: 1.01-1.20) and aircraft noise annoyance at night in females (OR=1.28; 95% CI: 1.01-1.63), were significantly associated with an increase in MI risk.

Table 5: Association between noise annoyance and MI-incidence

	Relative MI risk [OR, 95% CI]			
Annoyance [5-point scale]	Females Day	Females Night	Males Day	Males Night
Road traffic noise	1.03 (0.90-1.18)	0.98 (0.84-1.14)	1.04 (0.97-1.12)	1.10 (1.01-1.20)
Aircraft noise	1.13 (0.97-1.32)	1.28 (1.01-1.63)	1.01 (0.93-1.10)	1.05 (0.93-1.19)
Rail noise	0.96 (0.78-1.18)	0.94 (0.71-1.24)	0.92 (0.82-1.04)	0.99 (0.85-1.15)
Industrial noise	1.11 (0.89-1.39)	1.02 (0.76-1.36)	1.06 (0.93-1.21)	0.91 (0.77-1.08)
Construction noise	1.05 (0.93-1.20)	1.17 (0.87-1.57)	1.08 (1.00-1.17)	1.10 (0.87-1.39)
Other outdoor noise	0.99 (0.85-1.15)	1.00 (0.82-1.22)	0.96 (0.88-1.05)	0.96 (0.86-1.07)
Impact noise indoors	0.94 (0.79-1.11)	0.95 (0.75-1.20)	1.04 (0.95-1.14)	1.02 (0.90-1.16)
Other indoor noise	1.03 (0.88-1.21)	1.09 (0.89-1.33)	0.92 (0.84-1.02)	0.99 (0.87-1.12)

Discussion

In the present epidemiological study, the findings from an earlier study using largely the same methods were confirmed. A clear dose-response relationship showing an increase in risk with increasing traffic noise level was found. Male subjects that lived in streets with average A-weighted sound levels during the day of more than 70 dB(A) showed an increase in risk of myocardial infarction compared with those that lived in streets with less/equal 60 dB(A). The odds ratio of OR=1.27 (95% CI: 0.88-1.84) found in the total sample for this extreme group comparison was statistically not significant. In the sub-sample (stratified analyses) of subjects who had been living for at least 10 years at their present address an odds ratio of OR=1.81 (95% CI: 1.02-3.21) was found for the same comparison, which was significant. When multiple modelling was applied to assess the effect modifying impact of residence time an odds ratio of OR=1.34 (95% CI: 0.85-2.09) for the same comparison, which was smaller and not significant. The magnitude of these odds ratios should not be over-interpreted because of methodological limitations. Important, however, is the principal finding that stronger and in some cases statistically significant associations were found when subjects with longer residence times were considered. This is most obvious when the male subjects of the two highest noise categories are considered together in one category to increase the statistical power for the contrast. In the total sample not accounting for residence time, the odds ratio found for this group with sound levels during the day of more than 65 dB(A) was OR = 1.18 (95% CI: 0.93-1.49) and not significant. In the sub-sample accounting for residence time, however, the respective odds ratios of OR = 1.33 (95% CI: 1.00-1.76) and OR = 1.45 (95% CI: 1.03-2.05) were both significant when two different methods of analysis were applied.

The finding that the association was stronger and the estimated effect larger, when the residence time was considered in the analyses, is plausible and in accordance with the test hypothesis. The disease outcome under study has a long induction time. Particularly when chronic noise stress is considered as a potential cause, one would expect many years of exposure before pathological changes in the organism become manifest [46,73]. Also in other noise studies, residence time was found to be an important effect (exposure) modifier of the relationship between traffic noise and cardiovascular diseases [7,9,13,55]. In females, no higher MI risk was found with respect to the traffic noise level in the present study.

The finding that only in males an increase in MI risk was found with increasing traffic noise level, and not in females, is consistent with the fact that only in males a significant positive relationship between noise annoyance due to road traffic noise and MI incidence was found, and not in females. The results were not controlled for the intake of sex hormones, which may protect or promote adverse (noise-) stress effects [15,23]. In noise experiments females showed less vegetative reactions than males [40,56]. In a large cross-sectional study, a higher prevalence of high blood pressure was found in traffic noise exposed males but not in females [38]. The negative findings of a traffic noise and blood pressure study carried on females were discussed with respect to the use of contraceptives [21]. Furthermore, different time activity patterns may explain differences in noise effects between the sexes. Further analyses will focus on potential effect modifiers. Interaction effects have been shown in males exposed to high levels of environmental noise (at home) and occupational noise [6].

No explanation can be given at the moment for the strong protective effect found in a subgroup of the reference group. It may be attractive to consider only this group (subgroup 2) as a reference group in the analyses. Subjects from most of the other noise categories would then be significantly at higher risk, including females. However, any such analysis would be misleading due to the inadequate selection of a reference group. It would ignore the fact that the females of the large subgroup 1 were equally at risk. The validity of the noise assessment in the reference group is an essential point of the study and is discussed in the following.

The sound levels of reference subgroup 2 referred mostly to main roads in the distance, but not to the side street where the subjects' houses were located. In fact, 72% of these homes were in side streets that were directly entering a main road (tributary streets). The subjects' houses were so close to the junctions with the main road that exact sound level calculations regarding the main road were necessary. For subgroup 1 no exact sound levels can be given, but main roads were not within relevant distances to these subjects' houses (on acoustical grounds of sound propagation and attenuation). The maximum allowed speed in most of the side streets was reduced to 30 km/h, which, too, is an indicator of low traffic volume and low sound level. It should be noted that the distance of each individual house to main roads was explicitly assessed, despite whether it was on a main road or a side street. On the basis of worst-case scenario regarding the sound emission of the main roads it was decided, whether the sound level criterion of the reference group could possibly be violated. If so, exact calculations were carried out with respect to the actual sound emission of these main roads (which was found to be lower in most cases).

Misclassification of noise exposure from traffic in side streets dilutes the true noise effect. On the basis of measurements taken in side streets, it was estimated that approx. 10-15 % of subjects in side streets could have been exposed to sound levels of more than 60 dB(A) during the day. However, this applies equally to the subjects of subgroup 1 and subgroup 2. In fact, the impact of exposure misclassification might be larger in subgroup 2 (the one with the lowest MI risk) for logical and technical reasons of traffic flow composition. Subgroup 2 refers largely to side streets directly entering main roads, while subgroup 1 refers to the breakdown of the traffic flow on the side streets. With larger distances from main roads traffic volume decreases. Even a 20% misclassification of exposure in the reference group has only a marginal impact on the effect estimates and does not explain the large differences in risk between the two reference subgroups.

Furthermore, if one suspects differences in noise exposure between the two subgroups of subjects in the reference category, it is more reasonable to assume a lower exposure for subgroup 1. The calculated sound levels (day) for all subjects from subgroup 2 ranged from

>55 to 60 dB(A). The assessment of the sound levels in side streets of 4 districts of Berlin revealed that the sound levels in 50-70 % of the street-segments were below 55 dB(A), which suggests that the noise exposure of subgroup 1 on average, was less than that of subgroup 2. This is supported by the fact that subjects from subgroup 1 were least annoyed by traffic noise followed by subgroup 2 as shown in Figure 1. It gives the association between traffic noise level and annoyance ratings. Annoyance due to traffic noise shows an increase with increasing sound level, if reference subgroup 1 is considered as the least exposed. In social surveys, monotonous trends between sound level and annoyance are repeatedly found [27,49]. The finding, too, gives no reason to believe that subjects in subgroup 1 were exposed on average, to higher traffic noise than those in subgroup 2 – rather the opposite may be true.

According to the a-priori test-hypothesis of the study, the allocation of subjects was to be made on the basis of acoustical grounds of sound exposure. On these grounds, no distinction can be made between subjects in the reference group. The difference in MI risk between the two subgroups was due to unknown non-traffic noise related factors, which require further investigation from a psychosocial point of view.

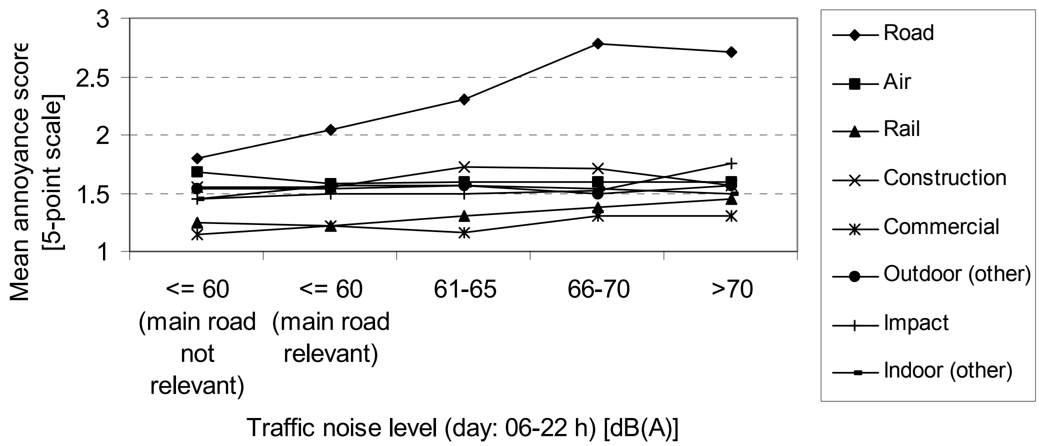

Figure 1: Association between traffic noise level and annoyance ratings due to different noise sources

Conclusion

The study results support the hypothesis that chronic exposure to road traffic noise increases the risk for myocardial infarction in males. The results of the previous study using a similar case-control design were largely confirmed. While the previous study suggested a threshold effect, a monotone increase in risk with increasing sound level was found in the present study. While earlier studies were not able to show significant results, the present study showed statistically significant results when subjects with many years of exposure (residence time) where considered. This is probably due to the fact that the assessment of noise exposure has considerably improved and in the present study, and exposure misclassification was reduced due to the availability of noise maps embedded in a detailed graphical information system. Individual exposure data from all potential sources of transportation noise around the subjects' houses were considered. The new results are another piece in the evaluation of the adverse health effects of long-term exposure to road traffic noise, which is an important environmental and public health issue [77]. The data can be used to improve the quantitative estimates derived from meta-analyses [43]. More detailed analyses regarding possible effect modifiers are in progress.

For references see part I of the report "Auswertung, Bewertung und vertiefende Analysen".