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Report to partners: Annoyance of residents living in urban areas

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A2: Annoyance of residents and evaluation of developments within SILENCE

Workpackage A2 aimed at

- the determination of annoyance in urban areas,
- the evaluation of attenuation measures developed within the SILENCE IP.

A2.1: Annoyance in urban areas

1 Introduction

Transportation noise is an environmental stressor that causes disturbances of communication, performance and sleep and thereby annoyance. The latter is the most frequently ascertained effect of noise in residents living in urban areas.

This task focused on annoyance of residents due to transportation noise while taking into account several possible influences such as demographic variables (age, gender) and noise sensitivity as a personal trait. For this an online questionnaire was designed

- to relate noise annoyance to noise load as ascertained by noise maps
- to determine the influence of noise sensitivity on annoyance
- and to detect possible cultural differences between European citizens of different member states.

2 Procedure and measurements

2.1 Questionnaire

The questionnaire, accessible via internet (www.ifado.de/SILENCE), is currently available in ten European languages (German, English, French, Dutch, Italian, Polish, Swedish, Hungarian, Spanish and Catalan). It consists of:

- *Demographic variables,* namely gender, age (categorized by 10-year-classes), employment (yes/no) and years living in the actual residential area.
- *Information on residential area* concerning the type of street (main/side street) and the installation of traffic calming measures (yes/no).
- *Noise perception and annoyance*: (1) Perception of noise levels in the residential area, using a 4-point scale (very noisy, quite noisy, quite calm, very calm), (2) ratings of chronic annoyance related to the preceding 12 months using the 5-point verbal ICBEN scale [ISO/TS 15666; Fields et al 2001], not at all, slightly, moderately, very, extremely) overall and separately for noises emitted from road, rail and air traffic.
- *Personal address.* The respondents can decide whether they remain anonymous or give their full address (zip code, town, street and house number) which is essential to get the appropriate noise load from maps.
- *Noise sensitivity.* Noise annoyance is influenced by noise sensitivity [Fields 1993, Job 1988, 1999, Miedema & Vos 1999] that was ascertained with a reduced version (NoiSeQ-R) of the noise sensitivity questionnaire [Schütte et al. 2007]. It ascertains noise sensitivity with 4 items each for the areas sleep, habitation and work (Griefahn et al. 2007). The respondents judge their agreement to each of the twelve items and to a control item using a 4-point scale (strongly agree, slightly agree, slightly disagree, strongly disagree).

After the completion of the questionnaire the respondents receive a feedback about their noise sensitivity.

2.2 Noise load

Noise maps are prescribed by the European Directive 2002/49/EC for built-up areas with more than 250,000 residents as well as for main streets with a traffic volume of more than 6 million vehicles/year, main railway tracks with more than 60,000 trains/year and main airports with more than 50,000 movements/year, separately for day and for night time. Though these maps should have been completed by July 2007 many communities are as yet not able to provide these data either because the calculations are not yet finished or as the data are currently under evaluation. Thus only half of the respondents could be assigned a noise load. The data are available in classes with 5 dB-steps in the internet. Munich and Genova provided the noise loads only for the respondents of this questionnaire. The online survey started – after a pilot study – in April 2007. Participants were made aware of the questionnaire by press releases.

3 Results

3.1 The sample (January 14, 2008)

After the elimination of anonymously filled in questionnaires and of those with invalid addresses, incomplete or non-plausible data as well as duplicates or questionnaires completed by non European citizens 4,124 questionnaires of respondents out of 17 countries were available for evaluation. Table 1 gives an overview concerning some demographic variables and aspects of the area related to the countries and to larger towns. The category 'Other' contains respondents from countries and cities with less than 100 completed questionnaires. Figure 1 shows the distribution of age.

Table 1: Number of participants, demographic variables, aspects of the residential area
NS: noise sensitivity (global score); Calm: traffic calming measures

	Number		**Gender**		**Age**			**NS**	**main**	**side**	**Calm**
Country	abs	%	fem	male	16-35	36-55	> 55	mean	street	street	yes
Austria	103	2.5	36.9	63.1	2.9	56.3	40.8	2.3	7.8	92.2	60.2
Germany	2561	62.1	46.7	53.3	26.5	46.2	27.3	2.1	27.8	72.2	38.7
Italy	369	8.9	42.5	57.5	37.1	55.8	7.0	2.1	25.5	74.5	8.9
Netherlands	364	8.8	35.4	64.6	39.0	42.9	18.1	2.0	19.8	80.2	85.2
Poland	420	10.2	45.2	54.8	69.8	23.6	6.7	2.1	32.6	67.4	11.0
Other	307	7.4	48.5	51.5	44.0	42.3	13.7	2.1	23.8	76.2	23.5
Total	4124	100.0	45.1	54.9	33.7	44.4	21.9	2.1	26.6	73.4	36.7
City		%									
Berlin	195	4.7	60.0	40.0	15.4	52.3	32.3	2.2	30.3	69.7	32.3
Cologne	238	5.8	42.4	57.6	16.4	53.4	30.3	2.1	31.5	68.5	32.4
Dortmund	292	7.1	46.9	53.1	54.8	27.7	17.5	1.9	24.3	75.7	45.2
Genova	154	3.7	44.2	55.8	21.4	72.7	5.8	2.1	23.4	76.6	5.2
Munich	263	6.4	39.9	60.1	30.4	49.4	20.2	2.0	40.3	59.7	33.5
Posnan	309	7.5	44.3	55.7	69.6	23.3	7.1	2.1	38.8	61.2	8.7
Other	2673	64.8	44.7	55.3	31.1	45.2	23.7	2.1	23.5	76.5	41.9
Total	4124	100.0	45.1	54.9	33.7	44.4	21.9	2.1	26.6	73.4	36.7

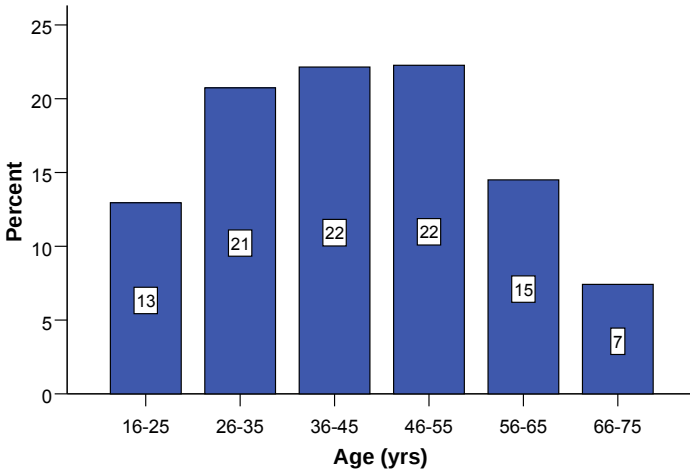


Figure 1: Percentage of participants grouped by age (boxes within columns indicate the percentages)

Due to the restricted availability of actual noise loads only 47% and 31 % of the respondents were assigned an L_{den} for road and for rail noise, respectively (Table 2).

Table 2: Number of participants grouped according to country and city whose noise load was determined by maps

	Road				**Rail**			
Country	$L_{Aeq,16h}$ (Day)	L_{night}	L_{den}	L_{den} & $L_{den\ estim}$	$L_{Aeq,16h}$ (Day)	L_{night}	L_{den}	L_{den} & $L_{den\ estim}$
Austria	3	94	94	94				
Germany	1108	1437	426	1512	1042	1166	139	1192
Italy	114	20	33	147	0	0	0	0
Netherlands	4	132	169	169	0	213	213	213
Poland	0	106	115	115	0	1	1	1
Other	2	3	63	65	0	1	15	1
Total	1231	1792	900	2102	1042	1381	368	1407
City								
Berlin	20	82	156	160	3	113	139	139
Cologne	236	236	0	236	236	236	0	236
Dortmund	289	289	0	289	288	289	1	289
Genova	114	20	33	147	0	0	0	0
Munich	0	207	203	203	0	0	0	0
Posnan	0	106	115	115	0	1	1	1
Other	572	852	393	952	515	742	227	742
Total	1231	1792	900	2102	1042	1381	368	1407

If only the equivalent noise levels for day and night were available, the respondent's L_{den}-class was estimated according to Sparman [2005] as follows:

$$L_{den} = L_{r,day} + \Delta_{ZB,} \text{ where}$$

$$\Delta_{ZB} = f(\Delta_{TN}) = 10 \cdot \lg\left(\frac{1}{2} + \frac{1}{6} \cdot 10^{\frac{1}{2}} + \frac{1}{3} \cdot 10^{\frac{10\,dB - \Delta_{TN}}{10\,dB}}\right) dB$$

and

$$\Delta_{TN} = L_{r,day} - L_{night}$$

3.2 Noise annoyance

Table 3 shows the results for noise annoyance overall and due to rail and road traffic noise. Two thirds of the respondents reported substantial annoyance (moderately, very, or extremely annoyed) within the last 12 months. Due to the ubiquitous occurrence of road traffic more persons were annoyed by this than by rail noise.

Table 3: Noise annoyance in percentages overall and due to road traffic and railway noise

n= 4124	Noise annoyance		
	Overall	Road	Railway
(1) not at all	8.5	16.7	67.0
(2) slightly	24.9	29.6	16.0
(3) moderately	26.5	23.1	8.7
(4) very	27.5	21.2	4.9
(5) extremely	12.6	9.5	3.4
Mean	2.6	3.1	2.8
SD	0.9	1.2	1.2

As indicated by higher correlation coefficients global noise annoyance is more determined by annoyance due to road traffic noise than due to railway noise (Table 4).

Table 4: Coefficients of correlation (Kendall's τb) between variable of noise annoyance

	Noise annoyance	
Noise annoyance	Overall	Road traffic
Road traffic	.434	
Railway	.171	.143

3.3 Noise level

Noise levels for rail and for road traffic were available for 1,792 and for 2,102 persons, respectively. Each participant was assigned one of five L_{den}-classes, and one of six L_{night}-classes each for road traffic and railway noise, respectively. According to Table 5 the number of respondents decreased with increasing noise levels.

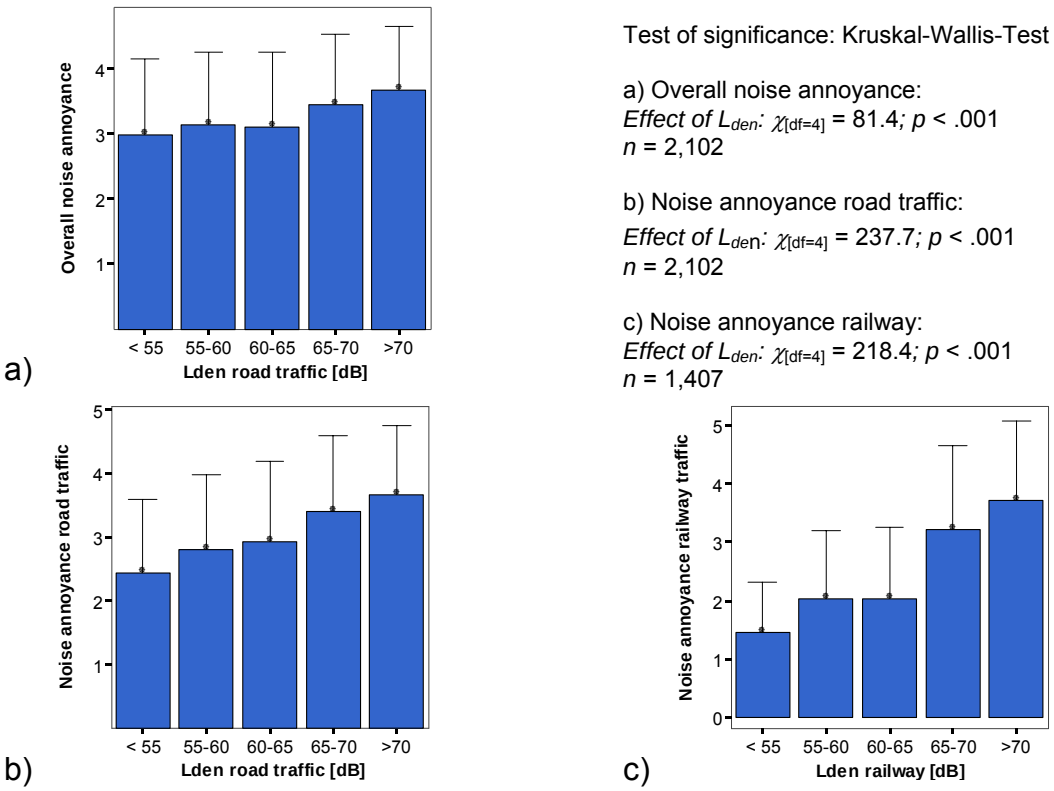
Table 5: Percentage of participants by railway and road traffic noise level classes (L_{den}, L_{night})

Noise level	L_{den}		Noise level	L_{night}	
[dB]	Road	Railway	[dB]	Road	Railway
			< 50	54.0	79.9
< 55	35,6	77.7	50-55	20.1	10.1
55-60	23.1	11.0	55-60	12.3	6.2
60-65	16.9	6.1	60-65	10.2	2.5
65-70	12.7	3.5	65-70	3.1	0.9
>70	11.7	1.7	> 70	0.4	0.4
n	2102	1407	n	1792	1381
	Correlation with annoyance (p < 0.01)				
	0.269	0.294		0.333	0.336

3.4 Association between noise annoyance and noise level

Annoyance overall and due to both traffic noises increased with noise load as shown in Figure 2. The correlation coefficients for the relations between annoyance and

noise loads are given in the bottom line of Table 5 showing that these relations are highly significant.



Test of significance: Kruskal-Wallis-Test

a) Overall noise annoyance:
Effect of L_{den}: $\chi_{[df=4]} = 81.4$; $p < .001$
$n = 2{,}102$

b) Noise annoyance road traffic:
Effect of L_{den}: $\chi_{[df=4]} = 237.7$; $p < .001$
$n = 2{,}102$

c) Noise annoyance railway:
Effect of L_{den}: $\chi_{[df=4]} = 218.4$; $p < .001$
$n = 1{,}407$

Figure 2a-c: Noise annoyance overall (a) due to road traffic (b)and to railway traffic (c) related to the corresponding L_{den}.

For the same noise level class those participants for whom the same noise levels of both transportation modes were available (n = 1,281) reported higher annoyance due to road than due to railway noise (Figure 3). This is particularly true for participants exposed to less than 65 dB L_{den} (Source: F[1, 89.6] = 45.8; Noise level: F[1, 89.6] = 86.4; Source*Noise level: F [4, 76.8] = 6.6; for all effects p < .001).

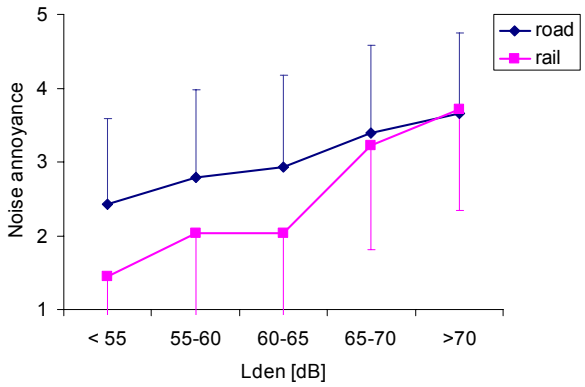


Figure 3: Annoyance due to railway and road traffic noise related to L_{den} *for participants for whom noise load of both sources could be determined (n = 1,281)*

3.5 Noise annoyance and demographic factors

Annoyance due to transportation noise (road traffic, railway noise) was not associated with gender. There was, however, a numerically small but significant correlation

with age ($p < 0.01$, $r_{road} = 0.082$, $r_{railway} = 0.087$). This association is illustrated in Figures 4a-b for different noise level classes.

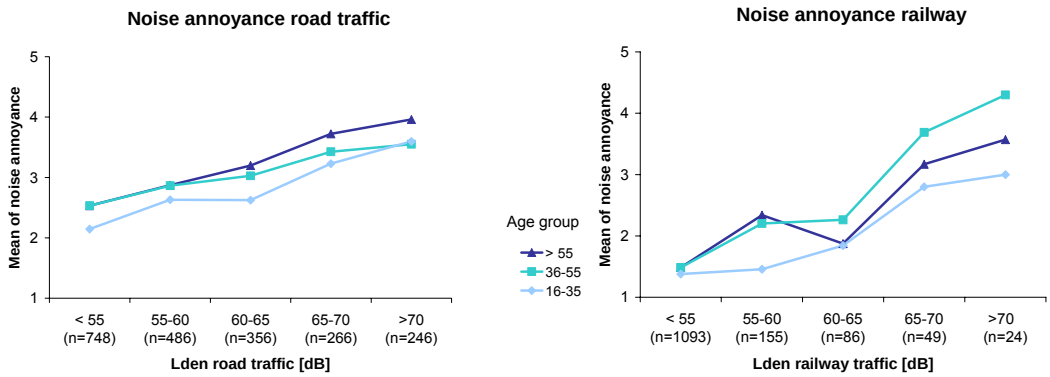


Figure 4a-b: Noise annoyance due to road traffic noise (left) and railway noise (right) separated by age group and noise level class (L_{den}).

Concerning situational aspects residents living in a main street (n = 620) were more annoyed by road traffic noise than those living in side streets (n = 1,482); (see Fig 5).

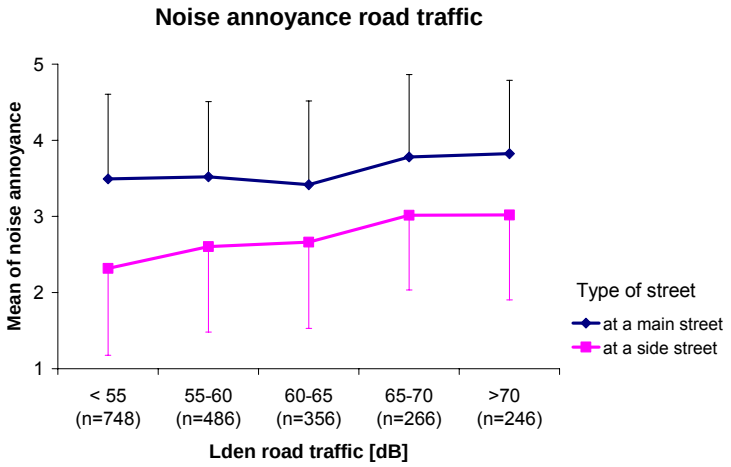


Figure 5: Noise annoyance due to road traffic separated by type of street (main street, side street) and noise level class (L_{den}). Mann-Whitney U tests for 'Type of street' as independent variable and noise annoyance as dependent variable in each noise level class: $U > 3002$; $p < .001$

3.6 Noise annoyance and noise sensitivity

Figure 6 shows the skewed distribution of noise sensitivity which indicates that the participants were rather sensitive and therefore more motivated than insensitive persons to participate in this study. 76% to 83% of the participants showed greater than average scores.

Noise sensitivity was significantly correlated with annoyance ($r_{road} = 0.119$, $p < 0.01$, $r_{railway} = 0.078$, $p < 0.01$), where the corresponding correlations with noise load were considerably lower ($r_{road} = -0.062$, $r_{rail} = 0.028$).

Figures 7a-b indicate that noise annoyance increased with noise load. At each noise level sensitive persons were more annoyed than less sensitive persons. The difference was, however, only significant for road traffic noise.

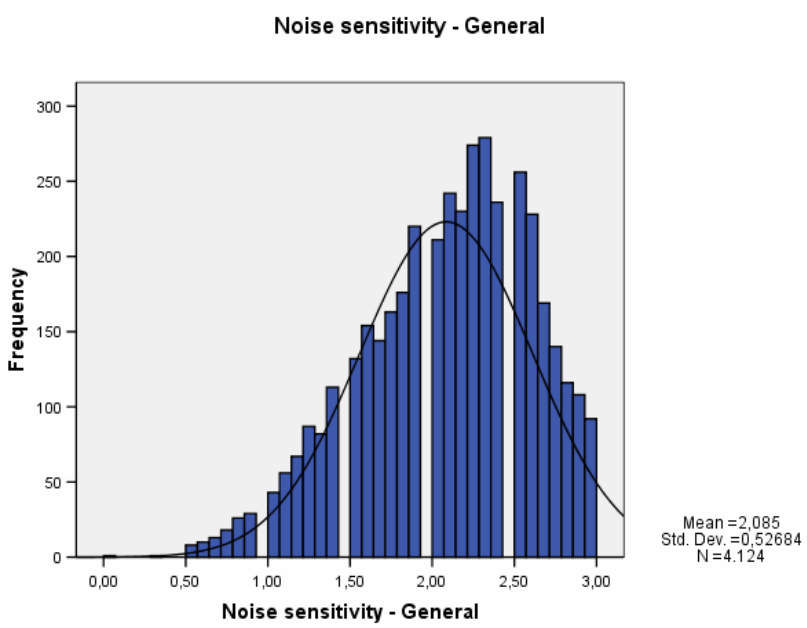


Figure 6: Number of participants related to noise sensitivity

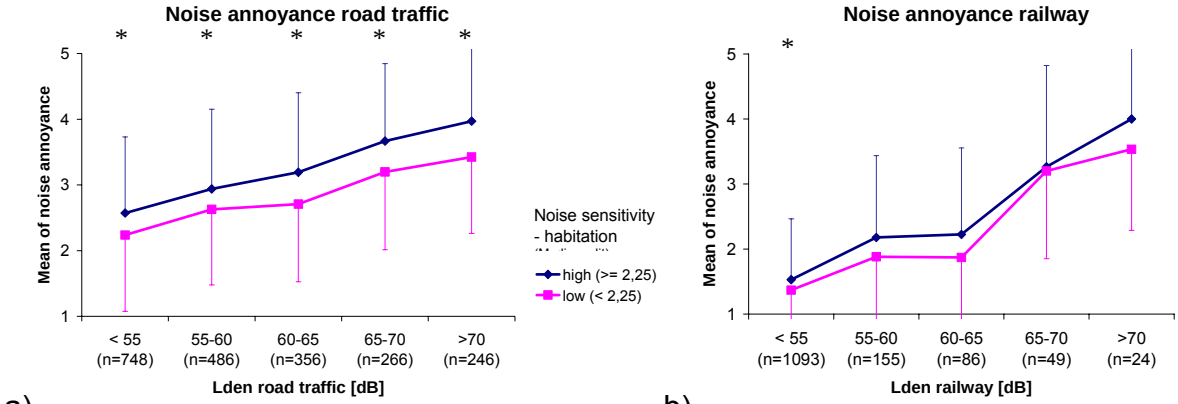


*Figure 7 a-b: Annoyance due to road (a) and rail traffic noise (b) separated by noise sensitivity (NSH; low/high) and noise level class (L_{den}). * p < .01 for the effect of NSH on noise annoyance (Mann-Whitney U tests)*

4 Road traffic noise European countries and cities

The following analyses were performed only for road traffic noise, the number of observations concerning railway noise was too small for similar analyses.

4.1 Noise annoyance in different European countries

The relationship between annoyance and road traffic noise was analyzed for five countries where at least 10 participants of at least three noise classes answered the questionnaire. These were Austria, Germany, Italy, Poland and The Netherlands.

There was a more or less steady increase in annoyance with increasing noise load in each of the five countries. There were significant differences for areas with levels of L_{den} < 70 dB (Figure 8). Post-hoc tests revealed that annoyance was significantly highest in Poland and Germany ($p < 0.01$) and lowest in Italy and in Austria.

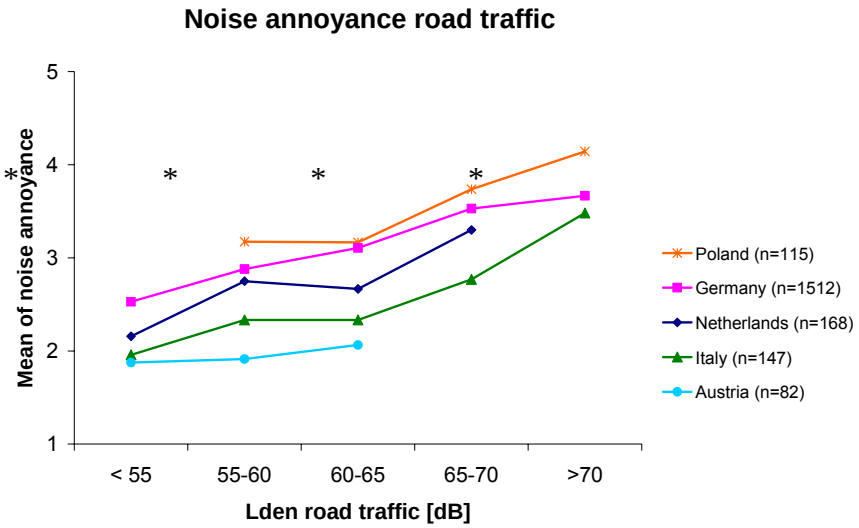


*Figure 8: Annoyance due to road traffic noise in three countries separated by noise level class (L_{den}). N= 2037; * p < .01 for the effect of country on noise annoyance (Kruskal-Wallis H tests)*

Participants from the 5 countries differ in the annoyance-related factors age, noise sensitivity concerning habitation (NSH) and type of street. However, the differences between countries remained stable even if after these factors were controlled in statistical analyses, meaning that other factors than these are the cause these 'cultural' differences (Table 6).

Table 6: Results of ANOVA with 'annoyance due to road traffic noise' as dependent variable, 'noise load' (5 classes) and 'city' as independent variables (model 1, 2) and additionally, 'age, 'type of street' and NSH as grouped covariates (model 2).

Factor	df	F	p
Model 1			
Noise load (L_{den})	4; 2037	9.721	**.000**
Country	4; 2037	15.126	**.000**
Noise load * Country	15; 2037	.646	.938
Model 2			
Noise load (L_{den})	4;2037	5.697	**.000**
Country	5;2037	10.220	**.000**
Noise load * Country	19;2037	.471	.264
Age (< / ≥ 45 yrs)	1;2037	16.151	**.000**
NSH (low/high)	1;2037	77.740	**.000**
Type of street (main / side street)	1;2037	196.578	**.000**

4.2 Noise annoyance in different European cities

Figure 9 shows the relationship between annoyance and noise load for those cities where at least 100 participants and a minimum number of 10 participants in at least 4 of the 5 noise classes answered the questionnaire. These were Berlin, Cologne, Dortmund, Genova, Munich and Poznan.

Annoyance increased with noise levels in the six cities, but differed between them. This is confirmed by non-parametric tests (Kruskal-Wallis H tests, p < .01) for all noise level classes. In addition, an ANOVA with 'noise load' and 'city' as independent variables and road traffic noise annoyance as dependent variable revealed two main effects but no interaction between 'noise load' and 'city' (Table 7, model 1). That

means that the relation between noise load and annoyance due to road traffic is almost similar in all cities, but that the degree of annoyance is different.

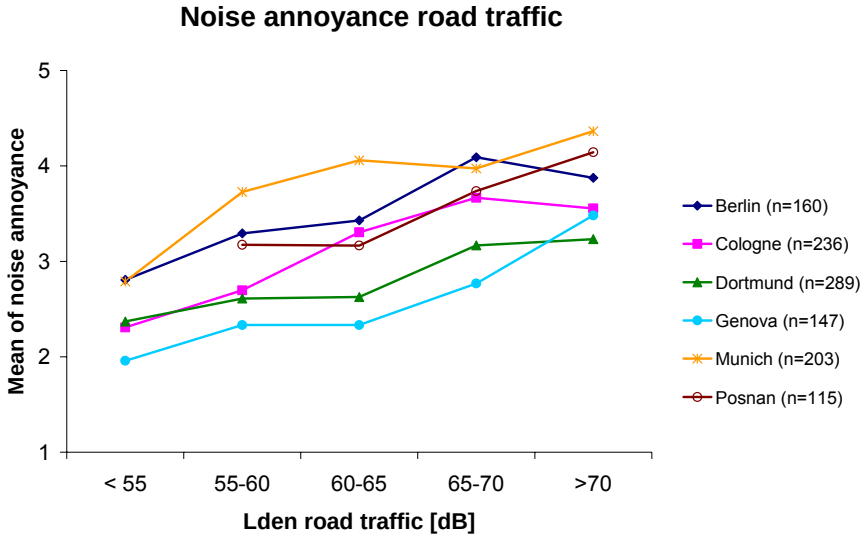


Figure 9: Noise annoyance due to road traffic noise in six cities separated by noise level class (L_{den})

In particular, participants from Genova and Dortmund reported less annoyance due to road traffic noise than participants from the other cities.

The participants of the different cities differed with respect to some of the personal and situational factors, which were associated with road traffic noise annoyance, namely age, noise sensitivity concerning habitation (NSH), and street type. The question is, whether the difference in one or more of these factors could explain the annoyance differences.

Table 7: Results of ANOVA with and 'annoyance due to road traffic noise' as dependent variable, 'noise load' (5 classes) and 'city' as independent variables (model 1, 2) and additionaly, 'age, 'type of street' and NSH as grouped covariates (model 2).

Factor	df	F	p
Model 1			
Noise load (L_{den})	4; 1150	38,537	**,000**
City	5; 1150	24,723	**,000**
Noise load * City	19; 1150	1,388	,123
Model 2			
Noise load (L_{den})	4;1150	14,641	**,000**
City	5;1150	13,806	**,000**
Noise load * City	19;1150	1,183	,264
Age (< / ≥ 45 yrs)	1;1150	14,683	**,000**
NSH (low/high)	1;1150	41,473	**,000**
Type of street (main / side street)	1;1150	87,525	**,000**

Table 8 shows that relatively more participants from Dortmund and from Genova, who were less annoyed than participants from other cities, reported to live in a side street and were less sensitive to noise. Age, which was positively correlated with annoyance could not explain the annoyance differences, as the relative number of older participants in cities with higher mean noise annoyance was not higher than in cities with lower mean annoyance. As Table 7 (model 2) indicates that the differences between cities remain after controlling for age, noise sensitivity (NSH) and type of

street. Each of all factors (noise load, cities, age, noise sensitivity and type of street) has a main effect on annoyance due to road traffic noise.

Table 8: Demographic data and noise sensitivity concerning habitation (NSH) of participants living in Berlin, Cologne, Dortmund, Genova, Munich, or Poznan abs: absolute; HP: hearing problems; NSH: noise sensitivity – habitation; Calm: Traffic calming

City	**Number**		**Age (yrs)**			**HP**		**NSH**		**Street type**	
			16-35	36-55	> 55		yes			main	side
	abs	*%*	*%*	*%*	*%*		*%*	*M*	*SD*	*%*	*%*
Berlin	160	22.1	17.5	52.5	30.0		11.3	2.2	0.5	35.6	64.4
Cologne	236	32.6	16.1	53.4	30.5		14.4	2.1	0.5	31.8	68.2
Dortmund	289	40.0	54.7	28.0	17.3		9.3	1.9	0.7	24.6	75.4
Genova	147	20.3	22.4	71.4	6.1		7.5	1.9	0.6	23.8	76.2
Munich	203	28.1	32.5	46.3	21.2		8.4	2.1	0.5	43.8	56.2
Posnan	115	15.9	73.0	22.6	4.3		13.9	1.9	0.6	64.3	35.7
Total	1150	100.0	35.4	44.9	19.7		10.7	2.0	0.6	34.9	65.1
Test of sign.			χ^2 234.3		p .000	χ^2 8.0	p .157	χ^2 47.8	p .000	χ^2 73.7	p .000

The differences in annoyance due to road traffic noise between participants from different cities are partly explained by noise sensitivity and type of street the participants live in. But there are certainly other factors that contribute to this difference.

The relative inaccuracy of the data provided by noise maps might contribute to the differences between cities. Some of these noise maps were brand new, others were calculated about 10 years ago (Dortmund, Cologne). Also in some cases the L_{den} had to be calculated on the base of the differences between the Leq for day time and night time.

5 Conclusion

4,124 residents of European built-up areas participated in an online survey on annoyance due to transportation noise. The aim of the study was to ascertain the relation between annoyance and noise exposure as indicated by noise maps of larger communities and to elucidate the significance of possible influences such as noise sensitivity, selected demographic and situational factors. Though the European Directive 2002/49/EC prescribes the calculation of noise maps up to July 2007 these data are not yet available, thus the analysis was possible for 2,102 and 1,407 persons for whom the noise load due to road traffic and railway traffic, respectively were available.

It has been shown that annoyance due to rail and road traffic was associated with noise load (L_{den}, L_{night}). The respective correlation coefficients of about $\tau b \approx .30$ are in line with coefficients published by other authors (e.g. Guski 2001, Wirth 2004). Concerning equal noise levels for road and for rail traffic annoyance was lower for the latter. This result is supported by several studies performed in the past [e.g. Fields & Walker 1980, Griefahn et al. 1999, Peeters et al. 1984]. Road traffic noise annoyance increased with age and noise sensitivity.

Even at the same noise load participants living in main streets were more annoyed than persons living in side streets. The reason for this may be differences in traffic characteristics.

The differences between European countries and cities were partly explained by the demographic variables but the differences remained even if controlling for these factors, meaning that other variables than the ascertained ones are responsible for the differences where the inaccurate noise data might contribute to.

6 References

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