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SELF-REPORT OF TRANSPORTATION NOISE EXPOSURE, ANNOYANCE AND NOISE SENSITIVITY IN RELATION TO NOISE MAP INFORMATION

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Self-report of noise exposure was compared with the information on noise maps while taking into account measures of self-reported annoyance and noise sensitivity. Self-report data were analyzed for 1495 subjects participating in a case-control study of hypertension from the Finnish Twin Cohort who had replied to a questionnaire in 1988. In addition, noise map information was included in analyses of the 218 study subjects living in the Metropolitan Area of Helsinki. The results show that: (1) In the factor analysis based on all subjects self-report of transportation noise exposure formed an own factor independent of the annoyance variables or noise sensitivity. Annoyance items loaded on to two different factors termed nighttime and daytime annoyance. Noise sensitivity did not load to either of the factors of annoyance. For the subsample with noise map information, the results indicated that: (2) Noise sensitivity was independent of noise map information. (3) Subjects with high noise sensitivity reported more transportation noise exposure than subjects with low noise sensitivity and they reported aircraft, railway and road traffic noise exposure outside the environmental noise map areas almost twice as often as non-sensitive subjects. (4) Noise map information and self-report of noise exposure were consistently associated when aircraft noise was considered. Self-report of noise related items may supplement noise map information in noise protection.

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1. INTRODUCTION

Whether a sound is classified as noise depends in part on the quality of the auditory experience it produces [1]. Noise is unwanted sound and thus implicitly refers to a subjective classification of sound. In some situations, noise may adversely affect the health and well being of individuals and populations [1,2].

The main physical characteristics of sound are sound pressure level, sound frequency, type of sound and variation in time [1]. The determination of sound pressure levels of transportation noise can be based either on direct measurements or indirectly by using mathematical models derived from other information, such as number of vehicles, traffic

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speed regulations, truck traffic volume, distance to road, shielding by row of buildings and terrain (appendix A, (c)). Transportation noise maps normally give information on equivalent continuous sound pressure levels, L_{Aeq} and on time-weighted L_{Aeq}—values such as day–evening–night average sound levels, L_{DEN}.

Sound becomes noise when it has an undesirable physiological or psychological effect on people [1]. The information from questionnaires and interviews about transportation noise is based on subjective experience of noise [3–18]. Some findings have suggested that subjective reactions to noise better predict health problems such as blood pressure than does actual noise level [19].

There are studies where noise exposure measured by questionnaires or interviews and physical measurements have been compared [4–12, 14, 15]. Most of these studies have concentrated on the relationship between physical measurement of noise exposure and annoyance measured by questionnaire or interview. In these studies, different sound energy measures were used. Since Schultz published his single dose–response relationship for annoyance due to transportation noise in 1978 [20], an intense debate about the precise description of the curve has taken place [1]. From this dose–response relationship curve, we may be able to predict the proportion of persons who would be "highly annoyed", but we cannot predict which individuals will be in that group [12].

Noise sensitivity is more likely to be related to a disposition to react to noise in general than to the physical properties of noise [15]. It is a predictor of noise annoyance, an intervening variable between noise exposure and annoyance, which explains much of the variance between noise exposure and individual annoyance [8, 13]. It seems to be one of the factors which explain different responses and differences in annoyance of individuals exposed to the same noise levels. Annoyance and sensitivity to noise appear to be related, but not identical, concepts [14, 15]. Noise sensitivity has been found to be independent of noise level [8, 14] or it has been only marginally related to objective measures of traffic noise [15].

In laboratory studies, extensive questionnaires have been used to measure noise sensitivity [12, 16, 21, 22], whereas in community surveys noise sensitivity has more often been measured by short direct questions [8, 10, 11, 14, 16] such as "Do you think that you are sensitive to noise?" [11].

In community studies, noise-sensitive people have been more annoyed by road traffic noise compared with less noise-sensitive people. Also in laboratory studies, annoyance has been highly correlated with subjectively reported noise sensitivity [16] and highly noise-sensitive subjects have demonstrated greater physiological arousal, more defence/startle responses and lower habituation to noise than low-sensitive subjects [22].

The aim of the present study was to compare the information from questionnaires about transportation noise exposure with the information about noise exposure obtained from transportation noise maps, and to explore how this association is affected by noise sensitivity and noise annoyance.

2. MATERIAL AND METHODS

2.1. QUESTIONNAIRE

Data for these analyses came from individuals who replied to a questionnaire used in a case-control study based on the Finnish Twin Cohort [23]. In addition to items on noise, the questionnaire contained information of other covariates related to hypertension risk. In October 1988 a questionnaire was sent to 1005 twin-pairs discordant for hypertension. The 2010 individuals were aged 31 years or more. After two reminders, 1495 individuals

(688 men, 807 women) replied; the response rate was 74·7%. Their mean age was 55·5 years and standard deviation 11·6 years. The response rate was lower among older subjects and among men [3]. Fifteen per cent ($n = 218$) of the study subjects lived in the Metropolitan Area of Helsinki (Helsinki, $n = 134$; Espoo, $n = 41$; Vantaa, $n = 31$; Kerava and part of Tuusula, $n = 12$) and noise map information was collected for these individuals.

Questions used in the analyses of the present study were the following:

(1) Transportation noise was investigated using the question:

"For how many years have you noticed transportation noise in your home during your lifetime?"

The response alternatives were: not at all, less than 3 years, 3–6 years, 7–19 years, 20 or more years.

For the analyses we dichotomized this so that those who had not at all noticed transportation noise in their home were classified as not reporting noise, while all the others were classified as reporting noise.

(2) Noise source was investigated using the question:

"Which were the sources of the transportation noises you have noticed in your home during your lifetime: road traffic, train/tramway or aircraft noise?"

(3) Noise sensitivity was investigated using the question:

"People experience noise in different ways. Do you experience noise generally as very disturbing, quite disturbing, not especially disturbing, not at all disturbing or can't say?"

Noise sensitivity was determined from the answers in the following way:

"very disturbing" answers were ranked as high noise sensitivity, "quite disturbing" answers were ranked as quite high noise sensitivity, "not especially disturbing" answers were ranked as quite low noise sensitivity, "not at all disturbing" answers were ranked as low noise sensitivity.

For statistical analyses, subjects with high and quite high noise sensitivity were classified as noise sensitive and subjects with quite low and low noise sensitivity as non-sensitive subjects.

(4) Annoyance was determined by using 10 items. The core question was:

" Has the following occurred as a result of noise in your home?" The items were: disturbance of telephone conversation, disturbance when listening the radio/TV, disturbance of ordinary conversation, difficulties in concentrating on tasks such as reading, etc., disturbance of rest and relaxation, being startled, becoming nervous, disturbance whilst falling asleep, waking up at night or sleeping problems, shaking of the house. Each item was answered on the following scale: never, sometimes a year, sometimes a month, sometimes a week, every day.

(5) The following questions were used to define covariates for multivariate analyses:

Hypertension was investigated in the questionnaire by the questions: "Has a nurse or a doctor ever measured your blood pressure during the last five years?" Subjects who answered "yes" to the question were asked: "Has your blood pressure been elevated and have you used medication for hypertension during the last 5 years?" Current use of antihypertensive medication was determined according to the responses to a question concerning the number of days the subjects had used medication for hypertension during the previous year. Subjects who had used medication for more than 180 days were classified as having current regular medication for hypertension. These questions have previously been validated and there has been a good agreement between the blood pressure measurements, medical records and questionnaire-reported data [24]. Hearing impairment was investigated by the following question: "Is your hearing impaired?" Answers: no, I don't know or yes: a little, strongly, I use a hearing aid. Duration of residence at the current address was classified as having started before 1971, between 1971 and 1980 or between 1981 and 1988.The age groups were 31–50 years, 51–60 years and > 60 years defined by age at time of response to the questionnaire. The three social status groups were based on educational level and physical activity at work [25].

2.2. NOISE MAPS

The Metropolitan Area of Helsinki was chosen as the study area because both questionnaire data and other data about noise exposure were available. In other parts of Finland, noise maps are available only for the largest towns and airports and they cover only a small part of the country.

The Metropolitan Area of Helsinki consists of the cities of Helsinki, Espoo, Vantaa and Kauniainen (a small township with 5000 inhabitants in Espoo). Helsinki is the only major densely inhabited region in Finland. In 1988, the Metropolitan Area of Helsinki had 809 000 inhabitants, of which Helsinki had 490 000, Espoo had 165 000 and Vantaa had 149 000. The noise maps of Helsinki–Vantaa airport also include the city of Kerava and part of the city of Tuusula, northern neighbours of the city of Vantaa. In 1988, both Kerava and Tuusula had 27 000 inhabitants.

As far as transportation noise exposure in Finland is concerned, a recent review estimates that 17.8% of the inhabitants are exposed to road traffic, 1.2% to railway noise and 0.8% to aircraft noise. In the Metropolitan area of Helsinki, it is estimated that 24.8% of inhabitants are exposed to road traffic noise, 1.4% to railway noise and 7.3% to aircraft noise [26].

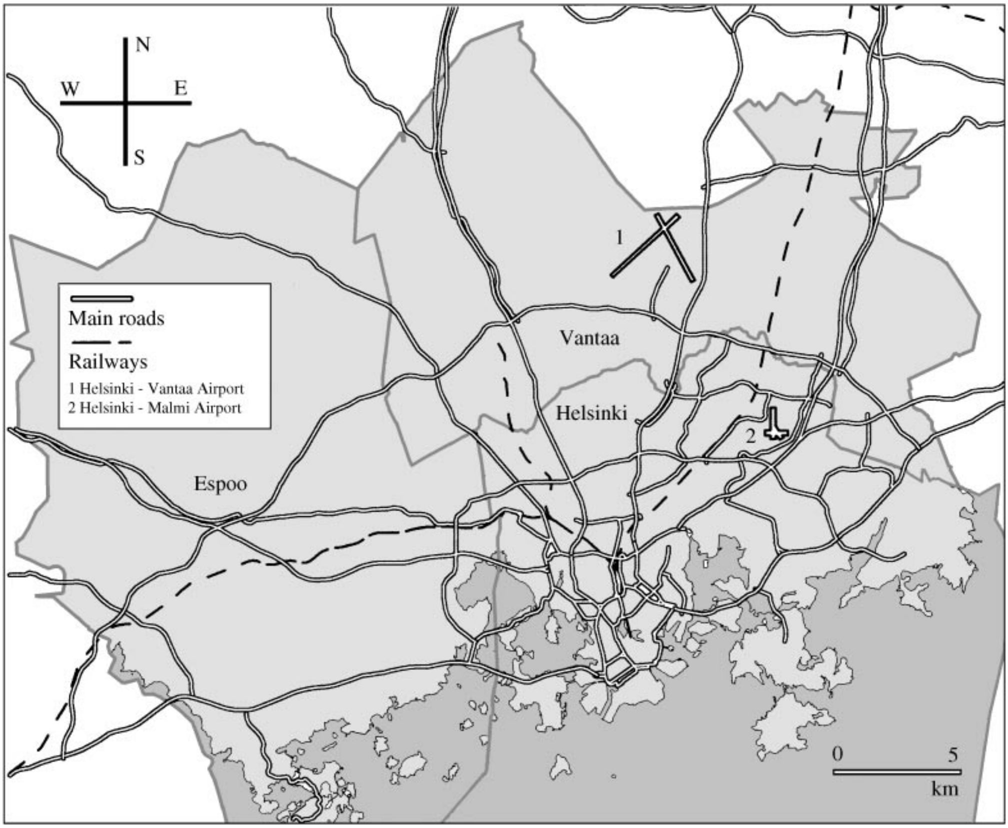

Figure 1. The Metropolitan Area of Helsinki. Copyright of the region map: Helsinki Metropolitan Area Council (YTV) Monitoring Departments 1997.

Noise maps containing transport noise information were available for road traffic noise, railway noise and the noise of the Helsinki–Vantaa and Helsinki–Malmi airports. The noise maps used included measurements as close as possible to 1988.

The noise map exposure level of each respondent was determined by their address at the time of the questionnaire study. The time the subjects lived in a particular residence was known, based on residence records kept by the Central Population Register (CPR) of Finland. Changes of the residence must be reported to the CPR by Finnish law.

In Helsinki, only road traffic noise exposure was available as a continuous dB-scale. For other transportation noise sources in Helsinki, and for all transportation noise sources in Vantaa and Espoo, the subjects were grouped into 5-dB categories. Subjects' noise map exposure levels were, (according to the noise maps): for road traffic noise: in Helsinki, continuous scale from 55 dB (levels were between 57 and 75 dB), Vantaa: 50–54, 55–59 dB; in Espoo: 55–59, 60–64 dB; for railway noise in Helsinki, Vantaa and Espoo, 50–54, 55–59 dB; for aircraft noise around Helsinki–Vantaa airport: 55–59 dB, 60–64 dB and around Helsinki-Malmi airport 45–49, 50–54, 55–59 dB.

For most of the analyses of the noise map information presented in this article, subjects were classified as exposed or not exposed according to the dB criteria given below for different types of transportation noise exposure.

2.2.1. *Road traffic noise*

The noise index used in the traffic noise maps of Helsinki, Vantaa and Espoo was the equivalent continuous A-weighted sound pressure levels, L_{Aeq} (Appendix A, (a), (b), (d)–(f)). On the road traffic noise maps for Helsinki in 1990, noise levels are calculated at 10 m from the centreline of the road at a height of 2 m (Appendix A, (a), (b)).

On the noise maps for Vantaa and Espoo, computer programs based on the Scandinavian model of calculating the road traffic noise were used (Appendix A, (c)). The road traffic noise maps for Vantaa were made in 1992 (Appendix A, (d)), while the traffic noise maps for Espoo dated from 1988 (Appendix A, (e), (f)). There were practically no changes in the noise levels during this period (Appendix A, (d)).

For the statistical analyses, the data of traffic noise for Helsinki, Espoo and Vantaa were combined. The cutting point for dichotomizing data for "exposed" and "not exposed" in these cities was 55 dB.

2.2.2. *Railway noise*

The noise index used in the railway noise maps of Vantaa and Helsinki was L_{Aeq} (Appendix A, (d), (g), (h)). In Vantaa the noise areas have been calculated according to the Scandinavian model of calculating the railway noise (Appendix A, (c)). The source of information about the rail traffic on the main railway used the situation in 1991 (Appendix A, (d)). In Helsinki, the railway noise maps were available only for some of the railways (Appendix A, (g), (h)). In Espoo, railway noise maps were not available. On the basis of the Vantaa and Helsinki railway studies, it was decided that the Helsinki and Espoo subjects should be classified in the following way; those living < 200 m from the rails were assumed to be exposed to railway noise and subjects living > 200 m from these railway were assumed not to be exposed to railway noise of $\geqslant 50$ dB.

In Helsinki, the tramway maps were used for estimating the exposure to tramway noise. Those living in addresses which were along the tramway lines were considered to be exposed to tramway noise, and those who did not live along the tramway lines were considered not to be exposed.

Because both groups exposed to railway and tramway noise were small and in the questionnaire exposure to railway and tramway noise was determined by a single question the two groups were combined for the analyses. For the statistical analyses, the data for railway noise were combined for all the cities of Helsinki, Espoo and Vantaa. The cutting point for dichotomizing the data for "exposed" and "not exposed" in all above-mentioned cities was 50 dB.

2.2.3. *Aircraft noise*

(1) *Helsinki–Vantaa airport* 1990 (*Appendix A*, (*i*)–(*k*)): For the Helsinki–Vantaa airport the L_{DEN}-maps (day–evening–night average sound level) (Appendix A, (i)–(k)) for domestic and international flights were used, the calculation of noise exposure being for 1990. The aircraft noise exposure area included areas from Helsinki, Espoo, Vantaa, Kerava and Tuusula. The cutting point for "exposed" and "not exposed" to aircraft noise of Helsinki–Vantaa airport was 55 dB.

(2) *Helsinki–Malmi airport* 1991, *small planes and helicopters* (*Appendix A*, (1)): The aircraft noise exposure area was restricted to the city of Helsinki. According to the number of flying operations, in 1991 this airport was the busiest airport in Finland. Almost all operations occur during daylight (Appendix A, (1)). The noise index used in 1991 was $L_{Aeq,07-22\,\mathrm{h}}$ (daytime equivalent level). In practice $L_{Aeq,07-22\mathrm{h}}$-levels do not differ essentially from L_{DEN}-levels around Helsinki–Malmi airport. The difference between them is less than 1 dB(A) (appendix A, (1)). The cutting point for "exposed" and "not exposed" to aircraft noise from Helsinki–Malmi airport was 45 dB, which in Finland is the lowest level used in the noise maps for general aviation airports (Appendix A, (m)). Because only a few individuals who answered the questionnaire lived in the area exposed to noise from Helsinki–Malmi airport, both groups (exposed to Helsinki–Vantaa and Helsinki–Malmi airport noise) were combined for further studies to improve the power of the analyses. For the statistical analyses, the data for aircraft noise was combined to include following cities: Helsinki, Vantaa, Espoo, Kerava and part of the city of Tuusula.

2.3. STATISTICAL ANALYSIS

Dichotomized noise exposure data from noise maps were compared with the information from the questionnaire. For the statistical analysis, Cohen's coefficient of agreement for nominal scales [27], Pearson chi-square and logistic regression models were used. Computer analyses were made using the BMDP package [28]. In a logistic regression model the following variables were considered: noise map information, noise sensitivity, sex, age, hypertension, social status, hearing impairment and duration of residence. Factor analysis [29], (principal components method with varimax rotation), was used to explore the relationship between annoyance (10 items), self-reported noise exposure (3 items) and noise sensitivity (1 item). The data were not dichotomized.

3. RESULTS

3.1. SELF-REPORTED MEASURES OF ANNOYANCE, NOISE SENSITIVITY AND NOISE EXPOSURE

In the factor analysis three factors were calculated (Table 1). Annoyance items loaded on to two different factors. Factor 1 includes annoyance items concerning waking up at night or sleeping problems, difficulty in falling asleep, becoming nervous, disturbance of rest and

TABLE 1

Factor loadings of self-report of transportation noise exposure, annoyance items and noise sensitivity after varimax rotation ($n = 1495$)

Variable	Factor 1	Factor 2	Factor 3
Self-report of transportation noise exposure			
Road traffic noise	0·261	0·047	0·686
Aircraft noise	− 0·002	0·127	0·591
Train/tramway noise	0·012	0·083	0·713
Annoyance			
Disturbance of telephone conversation	0·179	0·822	0·138
Disturbance of listening the radio/TV	0·240	0·821	0·184
Disturbance of ordinary conversation	0·264	0·839	0·177
Difficulties of concentrating on tasks such as reading, etc.	0·527	0·599	0·024
Disturbance of rest and relaxation	0·639	0·433	0·280
Being startled	0·628	0·290	0·071
Becoming nervous	0·685	0·454	0·069
Disturbance of falling asleep	0·805	0·240	0·093
Waking up at night or sleeping problems	0·818	0·070	0·147
Shaking of the house	0·316	0·159	0·542
Noise sensitivity	0·320	0·065	0·084
Variance explained	3·297	3·008	1·834

Factor loadings $\geqslant 0·6$ are considered to be of major impact.

relaxation and being startled. It was considered sufficient to describe nighttime annoyance. Factor 2 includes annoyance items about disturbance of ordinary conversation, disturbance of telephone conversation, disturbance of listening the radio/TV and difficulties of concentrating on tasks such as reading, etc. It was considered sufficient to describe daytime annoyance caused by transportation noise exposure. Factor 3 describes self-report of transportation noise exposure. The factor loadings of items after varimax rotation are shown in Table 1. Noise sensitivity did not load on to any of the factors.

3.2. NOISE SENSITIVITY AND SELF-REPORT OF NOISE EXPOSURE

The association between noise sensitivity and self-report of noise exposure was analyzed separately for all 1495 respondents, and among the 218 respondents living in the Metropolitan area of Helsinki. Table 2 shows that noise sensitivity has an influence on the self-report of transportation noise exposure in both groups ($p < 0·001$ and $p = 0·03$). Subjects with high noise sensitivity reported more noise exposure than subjects with low noise sensitivity. Among all respondents 38·2% of noise sensitive (high plus quite high noise sensitivity) subjects reported noise exposure whilst 25·5% of non-sensitive (low plus quite low noise sensitivity) subjects reported noise exposure. Of the Metropolitan area respondents, 53·9% of the noise-sensitive subjects and 41·3% of the non-sensitive subjects reported noise exposure.

3.3. NOISE MAP INFORMATION AND SELF-REPORT OF NOISE EXPOSURE

Most of the respondents in the Metropolitan area of Helsinki were exposed to moderate noise levels, although some subjects were exposed to high noise levels of road traffic noise.

TABLE 2

Noise sensitivity and self-report of transportation noise exposure

	Self-report of noise exposure			
	All respondents of the questionnaire		Respondents living in the Metropolitan Area of Helsinki	
Noise sensitivity	*n*	% of yes	*n*	% of yes
Low†	174	9·7	23	17·4
Quite low†	505	30·9	81	48·1
Quite high‡	423	37·6	71	56·3
High‡	106	40·6	18	44·4
Cannot say	157	12·7	9	22·2
Total	1365	28·9	202	46·0
Test for linear trend		39·84		4·76
D.f.		1		1
p-value		< 0·001		0·03

† Non-sensitive: low + quite low noise sensitivity.
‡ Noise sensitive: quite high + high noise sensitivity.

TABLE 3

The association between self-report of transportation noise exposure with noise map information based on dichotomized variables

Item	*n*	Percent agreement	Cohen's kappa	95% CI	
Any transportation noise	203	53·7	0·06	– 0·08,	0·19
Source of the transportation noise					
1. Road traffic	199	62·8	0·10	– 0·04,	0·23
2. Aircraft	198	72·2	0·16	0·01,	0·31
3. Railway	194	84·5	0·16	– 0·03,	0·35

The variation of noise levels among exposed subjects was rather small. Only a few subjects were exposed to more than one type of transportation noise: nine subjects were exposed to both road traffic and railway noise, two subjects were exposed to road traffic, railway and aircraft noise. Nearly all of the respondents in the Metropolitan area of Helsinki had answered the question about the source of transportation noise they had noticed at their home (road traffic noise, $n = 199$; aircraft noise, $n = 198$; railway noise, $n = 194$). Sixty-eight (34%) of them reported road traffic noise, 49 (25%) aircraft noise and 21 (11%) railway noise.

Noise map information and self-report of noise exposure were statistically significantly associated only when aircraft noise was considered (Cohen's kappa: 0·16, 95% CI: 0·01, 0·31).

Self-report of road traffic noise exposure among those exposed, according to noise maps in the Metropolitan Area of Helsinki, was also analyzed in noise categories 55–59, 60–64, 65–69, 70 + dB. The proportion of subjects reporting noise exposure was computed and shown in Figure 2 by level of exposure. Self-report of road traffic noise inside the noise map area increased with increasing noise levels.

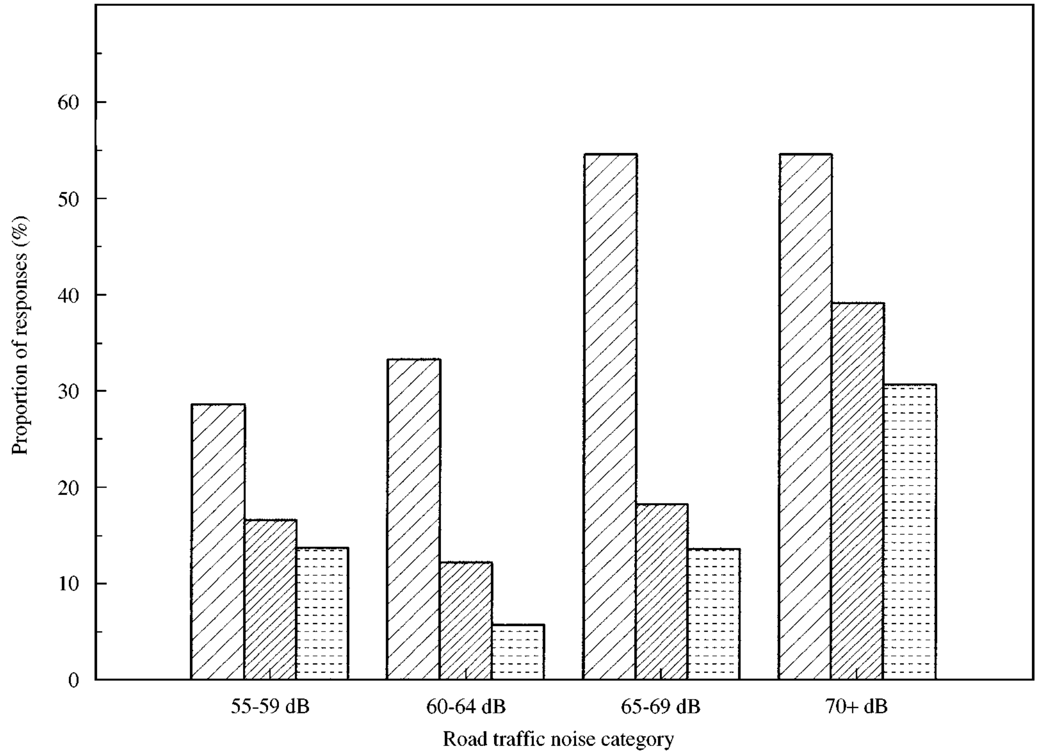

Figure 2. Percentage of self-report of road traffic noise exposure and nighttime and daytime annoyance items among subjects exposed to road traffic noise in the Metropolitan Area of Helsinki in different noise categories ($n = 48$). Self report of: ◻, road traffic noise exposure; ▨, nighttime annoyance; ⊟, daytime annoyance. Self-reported data of road traffic noise exposure was dichotomized so that those who had not at all noticed road traffic noise were classified as not reporting noise, while all the others were classified as reporting noise. Self-reported data of annoyance was dichotomized so that those who answered "never" on previously mentioned scale were classified as not reporting annoyance item, while all others were classified as reporting annoyance item.

3.4. NOISE MAP INFORMATION AND NOISE SENSITIVITY

Noise sensitivity appeared to be independent of noise map information. In the Metropolitan Area of Helsinki, 46·3% of the subjects who could determine their noise sensitivity and who lived in the area of noise maps were noise-sensitive. Corresponding 46·7% of the subjects who could determine their noise sensitivity and who lived outside the area of noise maps were noise sensitive. The difference between those living inside or outside the noise map areas comes from their ability to determine their noise sensitivity. Subjects living in the area of transportation noise were able to determine their noise sensitivity better than subjects living outside the area of noise maps: 6% of those subjects living outside noise map areas and 1% of subjects living in the areas of noise maps could not determine their noise sensitivity (Figure 3).

The answers of the respondents living in other parts of Finland were compared with the Metropolitan area respondents. In other parts of Finland, 12·7% of the respondents could not determine their noise sensitivity whereas in the Metropolitan area only 4·5% could not determine their noise sensitivity. Of those who could determine their noise sensitivity, 43·8% of the respondents of other parts of Finland were noise-sensitive, whereas 46·1% of the Metropolitan area respondents were noise-sensitive.

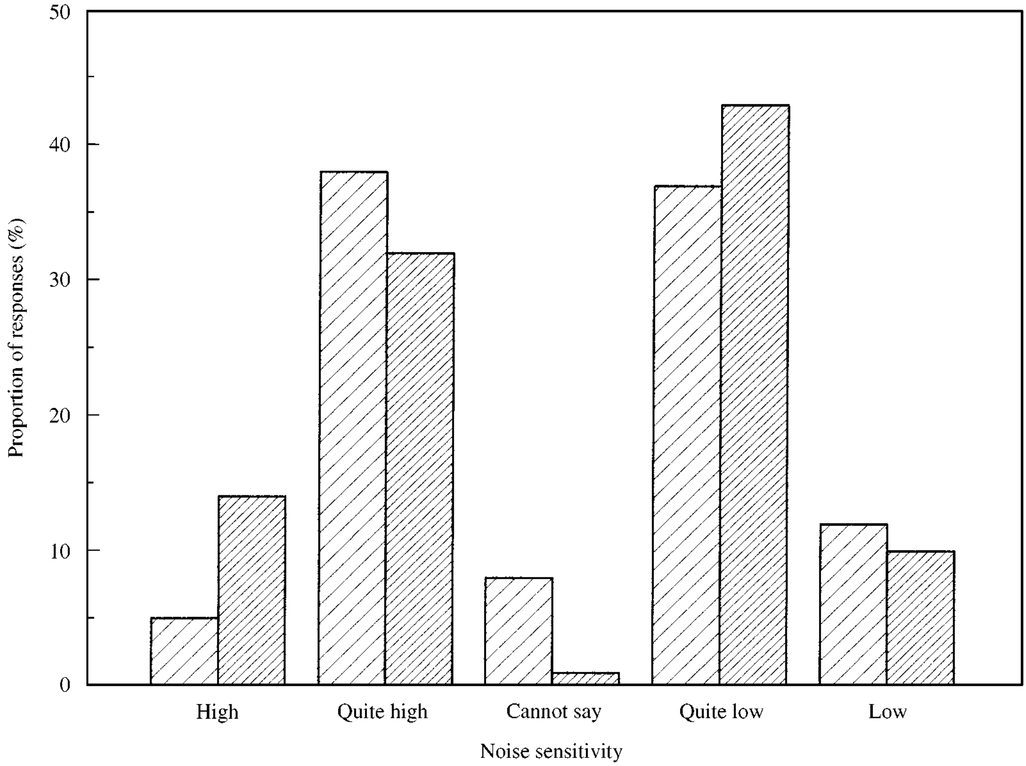

Figure 3. Noise sensitivity of subjects living in areas of transportation noise according to the noise maps in the Metropolitan Area of Helsinki ($n = 202$). ▨, not in noise map area; ▨, resident in noise map area.

3.5. NOISE MAP INFORMATION, NOISE SENSITIVITY AND SELF-REPORT OF NOISE EXPOSURE

Noise sensitive subjects report aircraft and road traffic noise outside the transportation noise map exposure areas almost twice as often as non-sensitive subjects (aircraft noise: non-sensitive 16·1%, sensitive 31·0%; road traffic noise: non-sensitive 25·6%, sensitive 40·3%), for railway noise the difference was even greater (non-sensitive 5·7%, sensitive 14·1%). Also in the areas of noise exposure according to noise maps, noise-sensitive subjects report noise exposure more often than non-sensitive subjects, but the difference between these groups is less obvious than in quiet areas (Table 4).

Log-linear contingency table analyses based on Table 4 indicated that noise map information ($p = 0{\cdot}03$) and noise sensitivity ($p = 0{\cdot}03$) were both independent predictors of the proportion of subjects reporting aircraft noise exposure. There was, however, no evidence for a synergistic (interaction) effect of the noise map information and noise sensitivity variables ($p = 0{\cdot}49$).

For railway noise exposure, only noise map information ($p = 0{\cdot}04$) was a significant predictor of self-report of railway noise, and interaction terms were not significant. In contrast, noise sensitivity was a significant predictor of self-report of road traffic noise exposure ($p = 0{\cdot}04$), while noise map information and the interaction term were not significant.

Logistic regression analyses were carried out to further explore these relationships while taking into account other study variables (Table 5).

TABLE 4

Noise map information, noise sensitivity and the self-reports of noise exposure to aircraft, railway and transportation noise

Noise map Noise exposure	Noise sensitivity	Self-report: percentage of subjects reporting noise exposure		
		Aircraft noise	Railway noise	Road traffic noise
No	No	16·1 ($n = 87$)	5·7 ($n = 87$)	25·6 ($n = 78$)
No	Yes	31·0 ($n = 71$)	14·1 ($n = 78$)	40·3 ($n = 67$)
Yes	No	40·0 ($n = 15$)	25·0 ($n = 12$)	38·5 ($n = 26$)
Yes	Yes	46·7 ($n = 15$)	28·6 ($n = 7$)	50·0 ($n = 18$)

n is the number of subjects with given noise map and noise sensitivity combination.

Although the crude odds ratios (OR) for noise map information and noise sensitivity are quite high in explaining the self-report of different types of transportation noise, the 95% confidence intervals include unity in all of the models (Table 5). When age, sex, social status, hearing, duration of residence and hypertension were included in the models which explain the self-report of different transportation noises, the odds ratios systematically diminished in explaining the self-report of road traffic noise or any transportation noise. Only the odds ratio of noise map information remained at a high level (2·40, with a wide 95% confidence interval) in the full model in explaining the self-report of aircraft noise (Table 5).

3.6. NOISE MAP INFORMATION AND ANNOYANCE

Self-report of annoyance was also analyzed in different noise categories (55–59, 60–64, 65–59, 70 dB) among subjects exposed to road traffic noise in the metropolitan area of Helsinki. The proportion of subjects reporting annoyance in the items loading to the nighttime and daytime annoyance factors (see results in section 1) was computed and is shown in figure 2 by level of exposure. Annoyance increased inside the noise map area with increasing noise levels.

4. DISCUSSION

In this study, self-report of noise exposure was compared with the information on noise maps while taking into account measures of self-reported annoyance and noise sensitivity. For most of the analyses, the noise map data relating to subjects was dichotomized into two groups: "exposed" and "not exposed" to transportation noise in order to minimize problems caused by potential misclassification of the data. No information about the locations of individual flats in apartment buildings was available (i.e., whether they faced or did not face the street), which may weaken the association. The available noise maps used different dB-criteria. The variability of the noise exposure map criteria may have had some influence on the results. Because the number of subjects was rather small ($n = 218$), analyses using more categories with the noise map subset of data would have led to small numbers in many cells, and caused a "sparse data" problem. Traffic noise exposure analyses using several noise categories gave essentially the same results.

TABLE 5

Noise map information and noise sensitivity in explaining the self-report of transportation noise exposure, logistic regression models

		Crude OR	Full model† OR
Road traffic noise			
Noise map:	No	1·00	1·00
	Yes	1·64	1·35
	95% CI	0·83, 3·28	0·60, 3·07
Noise sensitivity:	No	1·00	1·00
	Yes	1·81	1·10
	95% CI	0·95, 3·45	0·55, 2·20
Aircraft noise			
Noise map:	No	1·00	1·00
	Yes	2·28	2·40
	95% CI	0·99, 5·25	0·90, 6·40
Noise sensitivity:	No	1·00	1·00
	Yes	1·84	1·72
	95% CI	0·92, 3·68	0·77, 3·88
Railway noise			
Noise map:	No	1·00	1·00
	Yes	3·38	3·08
	95% CI	0·95, 12·00	0·75, 12·70
Noise sensitivity:	No	1·00	1·00
	Yes	2·08	1·56
	95% CI	0·76, 5·71	0·50, 4·96
Any noise			
Noise map:	No	1·00	1·00
	Yes	1·11	1·21
	95% CI	0·60, 2·03	0·62, 2·38
Noise sensitivity:	No	1·00	1·00
	Yes	1·55	1·13
	95% CI	0·85, 2·83	0·58, 2·21

† Models include sex, age, hypertension, social status, hearing, duration of residence and noise variables.

The noise maps were drawn in 1988–1992. There were practically no changes in noise levels during this period according to the Environmental Centers of Helsinki [30] and Vantaa (Appendix A, (d)). Only a few subjects were exposed to more than one transportation noise source, according to the noise maps. It is known, however, that observers can identify and assess a specific community noise in a mixture of community noises [31].

Self-report of noise exposure and noise map information were best associated when aircraft noise was considered. In this study, the aircraft noise exposure was studied around a rather large airport and around a small one (only for small planes and helicopters) and the data were combined for further studies. The nature of noise exposure and community reaction at small airports may differ from that at large airports. For example, the distribution of flyover noise levels in some areas near small airports can be highly bimodal. It is also possible that for the same aircraft L_{DN} values, residents of neighbourhoods near the small airport might simply hear more overflights than residents of neighbourhoods near the large airport [32]. In this study, there were weaker associations between noise map information and the self-report of noise exposure for road traffic noise. Both self-reported noise exposure and annoyance increased with road traffic noise category inside the noise exposure area of noise map. In previous studies, noise exposure level has been strongly associated with annoyance and for equal L_{DN} aircraft noise and highway noise have been more annoying than other road traffic noise, which in turn is more annoying than railway noise [1, 33–35].

In this study, noise sensitivity was determined according to the answers to the question about experience of noise in general. In the study of Öhrström *et al.*, different scales of noise sensitivity (a large questionnaire developed by Weinstein and an open scale) have been compared and they were highly correlated with each other [16]. In the study of Griffiths and Delauzin, the reliability of the self-rating noise sensitivity scale was found to be low but significant [17]. Noise sensitivity was in this study independent of noise map information, which is in agreement with previous studies [8, 14].

Of all respondents to the questionnaire, 38·4% were noise-sensitive (high or quite high noise sensitivity). In other studies, the percentage of noise-sensitive subjects has been 25–43·3% [8, 10, 18]. In these studies, different scales of noise sensitivity were used. This may explain the large variation in the proportions of noise-sensitive subjects. It could be speculated that in Finland, noise sensitivity may be relatively high because it has long been a sparsely populated agricultural country and urbanization has only recently occurred.

The concept of noise annoyance is significanty different when expressed in different languages. It is a multifaceted concept, covering immediate behavioural noise effect aspects, such as disturbance and interfering with activities and evaluative aspects, such as nuisance, unpleasantness and getting on one's nerves [36]. The question of annoyance have covered most of these aspects. In the concept of noise sensitivity, there may also be semantic differences in different languages. In factor analysis, the specific item of noise sensitivity did not load on the items of annoyance.

Noise sensitivity was an important factor in self-report of transportation noise exposure. Noise-sensitive subjects reported aircraft noise and road traffic noise exposure outside the noise exposure areas almost twice as often as non-sensitive subjects. In previous studies, it has been concluded that the moderating influence of self-reported noise sensitivity and annoyance may be greater at moderate than extreme noise levels [20]. In this study the difference was less obvious in the areas of noise exposure than in quiet areas, which is in accordance with previous studies.

5. CONCLUSIONS

In factor analysis, self-report of transportation noise exposure formed an own factor independent on the annoyance variables or noise sensitivity. Annoyance loaded on to two different factors termed nighttime and daytime annoyance. Noise sensitivity did not load to either of the factors of annoyance, and it was independent of noise map information. Noise-sensitive subjects report transportation noise more often outside the noise area than non-sensitive subjects. Aircraft noise maps were associated with the self-reports for noise exposure. Self-report of noise-related items may supplement noise map information in noise protection.

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APPENDIX A. SOURCES OF DATA

(a) Helsinki City Environmental Center 1991. Air Pollution and Noise caused by Road Traffic in Downtown Helsinki in 1991 (in Finnish).
(b) Helsinki City Planning Office 1987. The Number of Individuals Living in the Area of Road Traffic Noise in Helsinki 1987 (in Finnish).
(c) Finnish Ministry of the Interior, Department of Environmental Protection 1981. Model of Calculating the Road Traffic Noise, Helsinki (in Finnish).
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