Traffic noise and annoyance in a Swedish context

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ABSTRACT

Source specific exposure-response functions for traffic noise and annoyance have been developed within the framework of the WHO Environmental Noise Guidelines 2018. These functions can be valuable tools in health impact assessments. However, local conditions may affect their generalizability. In this study, we aim to compare the established exposure-response functions for traffic noise and annoyance to similar curves developed within a Swedish sample. Furthermore, we explore the annoyance response in relation to several moderating factors. The analyses are based on 12 360 responders from the Environmental-Health Questionnaire 2015 in Stockholm County. Exposure to road and railway noise was modelled using a simplified version of the Nordic Prediction Method. For aircraft noise, data was obtained from Swedavia. The results show that the benchmark of 10 % highly annoyed is reached at 52, 61 and 44 dB dB L_{den} for road, railway and aircraft noise, respectively. This corresponds well to the WHO curves for road and aircraft (53 and 45 dB L_{den}, respectively), but not for railway noise (54 dB L_{den}). Moderating effects on annoyance was found for building type, year of construction and apartment orientation.

BACKGROUND

Exposure to noise from the transport sector is a common and increasing environmental health hazard, in Sweden as well as internationally. Noise exposed populations typically experience many different disturbances, for example general annoyance, communication difficulties and sleep disturbances. Regarding annoyance, source specific exposure-response functions have been developed within the framework of the WHO Environmental Noise Guidelines 2018, based on several international surveys [1, 2]. These functions can serve as valuable tools in health impact assessments; however, local conditions may affect their generalizability. For example, factors such as construction year of buildings, soundproofing measures, and access to a quiet side may modify the annoyance response.

In this study, we aim to compare the WHO exposure-response functions for traffic noise (road, railway and aircraft) and annoyance to similar curves developed within a population sample from Stockholm County. Furthermore, we explore the annoyance response in relation to several moderating factors.

METHODS

Study population and questionnaire survey

This study is based on a sample of 12 360 men and women, aged 18-84 years, residing in Stockholm County. In 2015, the participants of the study answered a national environmental health survey, including questions on annoyance from road traffic, railway and aircraft noise as well as on the building in which the participants lived, e.g. building type, year of construction, soundproofing measures and apartment/window orientation [3]. In addition, information from registers was collected on various background factors, e.g. sex, age, country of birth, civil status, education and income.

Exposure assessment

The exposure estimation is based on the coordinate of the residential address for each participant in combination with input data needed for noise calculations, e.g. terrain (3D laser-scanned), ground surface (hard/soft), traffic flows on roads (>1000 vehicles/day) and rails, speed, buildings and noise screens/barriers. Exposure in $L_{Aeq,24h}$ and L_{den} was estimated by a simplified version of the Nordic prediction method at the most exposed façade of the building [4]. For aircraft noise, we used noise contours in L_{den} around the two major airports in Stockholm County, Arlanda and Bromma, estimated by the Integrated noise model (INM v 6.1) and based on radar tracks of the flights.

Statistical analyses

High noise annoyance was defined according to the ISO-standard [5], using the two highest categories on a five-grade verbal scale as indicator of high annoyance, i.e. persons reporting being much or very much annoyed by noise from each source, respectively. To assess exposure-response functions between traffic noise and the percentage of highly annoyed (%HA), we used logistic regression models and restricted cubic splines in case of non-logit-linearity. The estimated exposure-response curves from our sample were compared to the functions developed by Guski and colleagues [2]. In particular, we assessed the difference in noise level at which the WHO “critical effect” of 10 percent highly annoyed occurred. Furthermore, we explored the modifying effects of building type (single family home or apartment building), year of construction (before 1941, 1941-76, 1976-), soundproofing measures (yes/no; defined as measures regarding windows, fresh air valves or façade insulation) and apartment/window orientation (yes/no; facing a noisy road, railway or industry versus facing a more quiet court-yard, garden or nature) by stratified analyses using a log-likelihood ratio test to assess statistical differences between the strata, using a p-value of 0.05.

RESULTS

In total, 770 persons (6.3 percent) reported being highly annoyed by noise from road traffic (Table 1). Corresponding numbers for railway and aircraft noise were 151 (1.2 percent) and 413 (3.4 percent), respectively. At any given noise level, aircraft noise was associated with the highest proportion of highly noise annoyed persons.

Table 1: Number and percentage of highly annoyed persons (%HA) within the Environmental-Health Survey 2015 in Stockholm County, stratified on noise exposure categories (<40 to 70 dB $L_{Aeq,24h}$) and source of traffic.

	Much or very much annoyed by noise, N (%)		
Exposure category (dBA[1])	**Road traffic (N=12 245)**	**Railway (N=12 221)**	**Aircraft (N=12 221)**
<40	76 (1.5)	37 (0.4)	163 (1.5)
40-44	98 (4.0)	18 (2.1)	11 (16.2)
45-49	194 (8.6)	16 (3.2)	168 (17.1)
50-54	211 (14.7)	40 (9.5)	40 (33.6)
55-59	128 (18.2)	25 (13.4)	30 (60.0)
60-64	50 (17.2)	10 (17.5)	-[2]
64-70	10 (21.7)	5 (27.8)	-[2]
Total	770 (6.3)	151 (1.2)	413 (3.4)

[1] $L_{Aeq,24h}$ for road traffic and railway noise, FBN for aircraft noise. [2] Too few observations.

Figure 1 shows the modeled exposure-response functions for the associations between source specific noise levels in L_{den} and %HA in the sample from Stockholm County. For road traffic noise, the critical effect of 10 percent HA was reached at 52 dB L_{den} (approximately 49 dB $L_{Aeq,24h}$), for railway noise at 61 dB L_{den} (approximately 55 dB $L_{Aeq,24h}$) and for aircraft noise at 44 dB L_{den} (approximately 44 dB FBN).

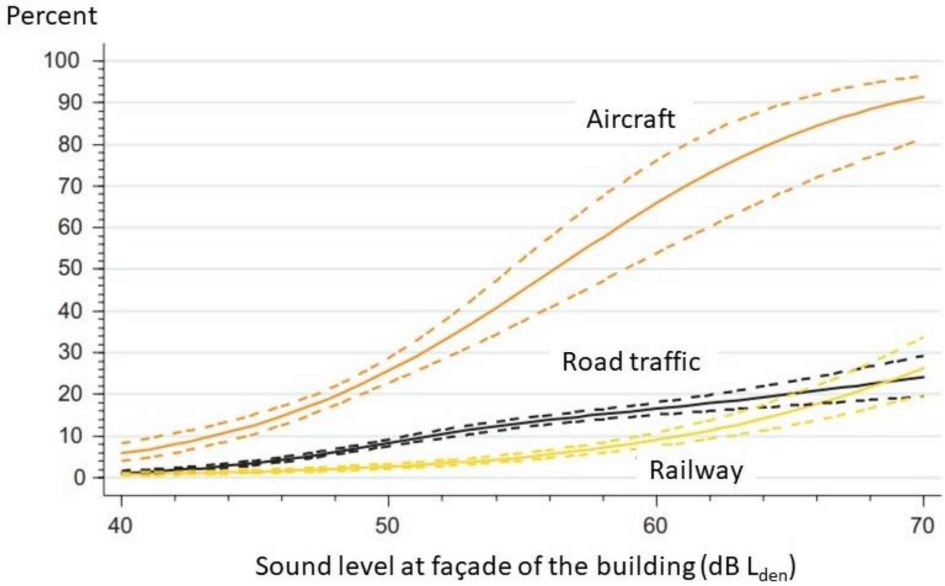

Figure 1: Modelled exposure-response functions for sound levels at the façade of buildings and percentage highly annoyed, for road traffic, railway and aircraft noise, respectively (including 95% confidence intervals).

The stratified analyses showed significant modification on the annoyance response by building type, construction year and apartment/windows orientation, but not for soundproofing measures. For road traffic noise, the percentage HA was higher among persons in single family homes as compared to those living in apartment buildings. With regard to construction year, the annoyance response was highest for buildings constructed during the years 1941-76 and lowest for those constructed after 1976 (Figure 2). Furthermore, people living in homes facing a noisy side were more disturbed than those having windows towards a quieter side. For railway noise and aircraft noise, similar but not always consistent patterns were shown.

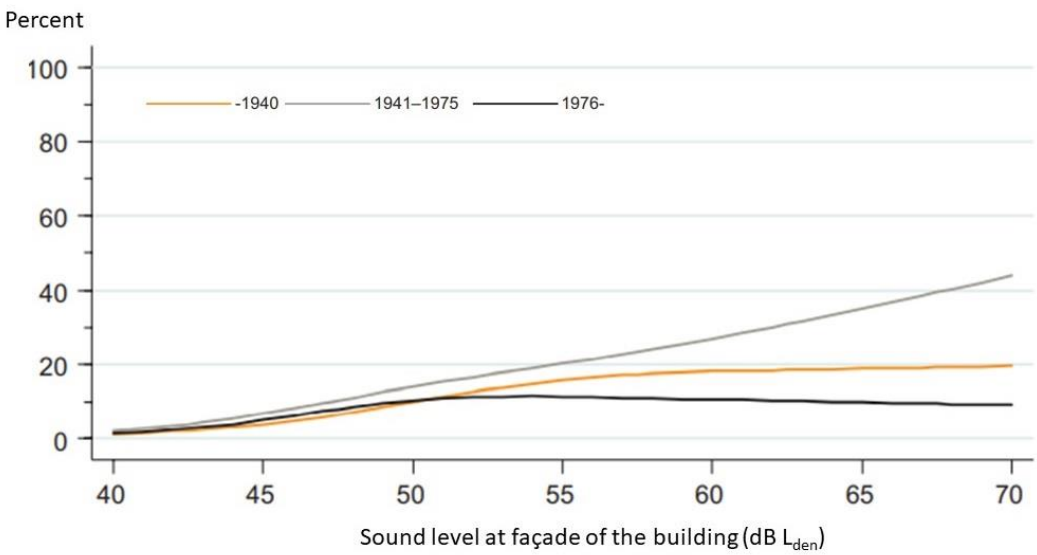

Figure 2: Modelled exposure-response function for sound levels of road traffic noise at the façade of buildings and percentage highly annoyed, stratified on construction year of the building.

DISCUSSION

The results of this study showed clear exposure-response patterns between the outdoor noise level at the most exposed façade of buildings and annoyance response in the adult population of Stockholm County. Comparing the three traffic noise sources, road traffic noise gave rise to the highest proportion of highly annoyed persons in total (6.3 percent, vs. 1.2 percent for railway noise and 3.4 percent for aircraft noise). However, at any given noise level, the percentage of highly annoyed was highest for aircraft noise, followed by road and railway noise. For road traffic and aircraft noise, the estimated noise level at which the critical effect of 10 percent HA was reached in our sample corresponded well with estimates from the WHO function; 52 vs. 53 dB L_{den} and 44 vs. 45 dB L_{den}, respectively [1, 2]. However, for railway noise, 10 percent HA was reached at a higher noise level in Stockholm County compared to the estimate of the WHO function; 61 vs. 54 dB L_{den}. The lower annoyance response for railway noise in our Swedish sample is not clear, but could be due to local variations in e.g. train types, placement and design of buildings and soundproofing measures.

Furthermore, there were indications of modification in the annoyance response by building type, construction year and apartment/window orientation. Persons living in single family homes were generally more annoyed than persons residing in apartment buildings. The reasons for this were not assessed within the scope of this investigation but could be caused by attitudinal factors of the homeowners, for instance the expectations of a quiet environment or worries about the housing value [6]. There was also a higher annoyance response for road traffic noise among those living in buildings constructed between 1941 and 1975. This is most likely a consequence of the construction of homes with relatively low soundproofing in Sweden during this time-period [7]. However, the results were not fully consistent for railway and aircraft noise, indicating a potential impact of renovation programs and additional sound proofing of these buildings. Finally, we observed a greater response in annoyance for people living in homes with windows facing a busy street, railway or industry in comparison with those having windows facing a courtyard, garden or nature. To design buildings with access to a quiet side could thus be an effective measure to reduce noise annoyance, which has also been shown previously [8]. It should be noted that these results should be interpreted with caution since we have only studied one factor at the time (by stratification) and not taken their covariation into account.

CONCLUSIONS

Residents of Stockholm County, Sweden, are annoyed by noise from road and aircraft traffic to the same extent as can be estimated from the WHO exposure-response functions. However, for railway noise, the Swedish residents appear less annoyed than what can be expected from the WHO curves. Building type, year of construction and apartment/window orientation may modify the annoyance response.

Acknowledgements

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