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# Social inequities regarding annoyance to noise and road traffic intensity

## Results of the German Health Interview and Examination Survey for Adults (DEGS1)

## Background and purpose

The Robert Koch Institute (RKI) conducted the German Health Interview and Examination Survey for Adults ("Studie zur Gesundheit Erwachsener in Deutschland", DEGS1) between November 2008 and December 2011 on behalf of the German Ministry of Health. The objective of DEGS1 was to collect representative data on the health situation of the adult population in Germany. The focus of scientific research is not only on investigating the health condition of the population in the context of their socioeconomic situation—a longstanding subject of sociomedical research—but increasingly also on determining the potential influence of environmental burdens on health. One question discussed in this respect is whether the socially unequal distribution of environmental burdens is partly responsible for the observed imbalance in the distribution of health and sickness [1]. For this reason it is important to investigate the relationship between socioeconomic situation and environmental exposures/environmental resources. A better understanding of this relationship is necessary in order to identify vulnerable population groups and minimise the health risks associated with environmental exposures [2, 3]. According to recent representative surveys, almost 80% of the German population believe that environmental problems impair their health, with a 30% saying that environmental problems have a strong or very strong impact on their health [4, 5]. The high number of publications on the issue of environmental exposures and social status reflects the increasing scientific interest in this topic in Germany in recent years [6, 7, 8, 9, 10, 11, 12]. These publications show that groups with lower social status can be exposed to a greater extent and more frequently to environmental burdens than populations with higher social status [6, 7, 8, 13, 14]. Finally, this issue is also of major political relevance, as underlined by the various activities of the World Health Organization (WHO) [15] in this area such as the Ministers' Conferences held in Budapest in 2004 and Parma in 2010 [16].

DEGS1 also included questions on environmental conditions of the study participants that might have negative impacts on health, in particular regarding noise annoyance in the home setting due to various noise sources and road traffic intensity.

In a first descriptive analysis, in this paper the widespread of annoyance to noise and road traffic intensity at residential address is investigated among the adult population of Germany and to what extent annoyance and exposure differ in respect to socioeconomic status and housing conditions of the study participants.

## Material and methods

### Study population

The German Health Interview and Examination Survey for Adults (DEGS) is part of the health monitoring system at the Robert Koch Institute (RKI). The concept and design of DEGS are described in detail elsewhere [17, 18, 19, 20, 21]. The first wave (DEGS1) was conducted from 2008–2011 and comprised interviews, examinations and tests [22, 23]. The target population comprises the residents of Germany aged from 18–79 years. DEGS1 has a mixed design which permits both cross-sectional and longitudinal analyses. For this purpose, a random sample from local population registries was drawn to complete the participants of the German National Health Interview and Examination Survey 1998 (GNHIES98). A total of 8,152 persons participated, including 4,193 first-time participants (response rate 42%) and 3,959 revisiting participants of GNHIES98 (response rate 62%). There were 7,238 persons who attended one of the 180 examination centres, and 914 were interviewed only. The net sample permits representative cross-sectional and time trend analyses for the age group from 18–79 years in comparison with GNHIES98 (n=7,124) [21].

**Tab. 1** Sociodemographic indicators, socioeconomic indicators and spatial indicators of the DEGS1 study, unweighted case numbers and relative frequencies (results in percent)

| Indicator/categories | Cases (n) | Frequency (%) | Frequency (%) |
|---|---|---|---|
| | Unweighted | Unweighted | Weighted |
| **Age group** | | | |
| 18–29 | 1,073 | 13.4 | 18.7 |
| 30–39 | 1,014 | 12.7 | 14.8 |
| 40–49 | 1,539 | 19.3 | 21.4 |
| 50–59 | 1,592 | 19.9 | 18.3 |
| 60–69 | 1,537 | 19.2 | 14.1 |
| 70–79 | 1,233 | 15.4 | 12.7 |
| Missing values | 0 | 0 | |
| **Sex** | | | |
| Men | 3,790 | 47.5 | 49.7 |
| Women | 4,198 | 52.6 | 50.3 |
| Missing values | 0 | 0 | |
| **Social status** | | | |
| Low | 1,269 | 15.9 | 19.9 |
| Middle | 4,692 | 58.7 | 59.9 |
| High | 1,915 | 24.0 | 20.1 |
| Missing values | 112 | 1.4 | |
| **Educational status** | | | |
| Low | 2,770 | 34.7 | 41.3 |
| Middle | 3,626 | 45.4 | 44.1 |
| High | 1,480 | 18.5 | 14.6 |
| Missing values | 112 | 1.4 | |
| **Occupational status** | | | |
| Low | 2,026 | 25.4 | 29.2 |
| Middle | 4,735 | 59.3 | 59.6 |
| High | 1,002 | 12.5 | 11.3 |
| Missing values | 225 | 2.8 | |
| **Equivalised disposable income** | | | |
| ≤60% median | 1,405 | 17.6 | 20.1 |
| >60–150% median | 4,876 | 61.0 | 60.2 |
| >150% median | 1,707 | 21.4 | 19.8 |
| Missing values | 0 | 0.0 | |
| **Rooms-per-capita** | | | |
| ≤1 room | 1,776 | 22.2 | 26.7 |
| >1–2 rooms | 4,131 | 51.7 | 52.2 |
| >2 rooms | 1,809 | 22.7 | 21.1 |
| Missing values | 272 | 3.4 | |
| **Residential region** | | | |
| West | 5,468 | 68.5 | 78.9 |
| East (including Berlin) | 2,520 | 31.6 | 21.1 |
| Missing values | 0 | 0.0 | |
| **Type of municipality** | | | |
| Rural | 1,464 | 18.3 | 16.0 |
| Small town | 1,967 | 24.6 | 23.3 |
| Mid-sized town | 2,316 | 29.0 | 29.6 |
| Large town | 2,241 | 28.1 | 31.1 |
| Missing values | 0 | 0 | |

## Annoyance to noise and road traffic intensity

Noise annoyance and road traffic intensity were surveyed using standardised age-specific self-administered questionnaires (one version for the 18–64 year olds and one for participants aged 65 and above). The perceived annoyance to various sources of noise (neighbourhood, road traffic, aircraft, industry/commerce, bars/pubs/discotheques, playing children and other noise) in the current apartment/dwelling was assessed with the question "In your current dwelling, to what extent do you feel annoyed by noise from the sources listed below?" Respondents were asked to rank the strength of annoyance separately for each source on a five-point scale from "5= extreme" to "1= not at all", and the answers were grouped into three categories ("strong to extreme", "slight to moderate" and "not at all") according to Kohlhuber et al. [24] and Mielck [25].

This analysis is restricted to the noise sources "road traffic noise", "neighbourhood noise" and "aircraft noise", as numerous national studies rank these three sources highest and an inclusion of other sources of noise would be out of the scope of the publication. This study did not ask about noise annoyance due to rail transport. In addition, the detailed analysis of level of noise annoyance only covers strong/extreme levels of annoyance because with this characteristic value the most marked associations are expected with social status or its sub-scales.

Road traffic intensity as a surrogate indicator for traffic-related air pollution was measured by asking about the street location of the dwelling based on the location of the apartment or house on the following types of streets:

- extremely busy through road,
- busy main or through road,
- side road with considerable traffic,
- side road with moderate traffic and
- road, service road, path, traffic calmed road with very little traffic.

Where the dwelling was located on more than one street, study participants should rank their dwelling only about the busiest of these streets.

For further evaluations, the characteristic values were used to form three categories representing extreme to high, considerable to moderate and very low road traffic intensity.

## Sociodemographic and socioeconomic characteristics

The sociodemographic characteristics of age and sex were taken from the self-administered questionnaires completed by participants.

Regional classification was based on place of residence in eastern Germany (including Berlin) and western Germany. Stratification by type of municipality was based on number of inhabitants as follows: rural with fewer than 5,000 inhabitants, small town with 5,000 to fewer than 20,000 inhabitants, medium-sized town with 20,000 to fewer than 100,000 inhabitants and large town with 100,000 and more inhabitants. The study looked not only at the aforementioned sociodemographic and regional characteristics but also at various socioeconomic indicators based on three-tier stratification focusing on educational background, occupational status and equivalised disposable income. "Educational background" was operationalised as an individual characteristic based on the school-based and occupational qualifications of the respondents, while occupation and income were defined as household characteristics. A detailed description of this operationalisation process can be found in this issue [26]. The distribution of the values was used to form quintiles for the variables educational and occupational status in order to differentiate between low (1st quintile), middle (2nd–4th quintile) and high educational and occupational status group (5th quintile). For the distinction of three income groups, the following threshold values were defined based on the median equivalised disposable income (1,250 €): ≤60%, >60 to 150% and >150% of the median. In addition, social status was determined using an index which includes information on school education- and vocational training, professional status and net household income (weighted by household needs)—the equivalised disposable income [26, 27, 28].


## Abstract · Zusammenfassung

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### Social inequities regarding annoyance to noise and road traffic intensity. Results of the German Health Interview and Examination Survey for Adults (DEGS1)

**Abstract**

To study the associations of annoyance to noise and exposure to residential traffic with sociodemographic, socioeconomic and regional characteristics as well as housing conditions, a population-based sample of 7,988 adults 18–79 years of age was studied in the German Health Interview and Examination Survey for Adults (DEGS1). Annoyance to noise and exposure to residential traffic were assessed by self-administered questionnaires. A total of 6.3% of the participants reported a high to very high exposure to residential traffic noise, 3.7% to neighbourhood noise and 2.1% to aircraft noise. An excessive exposure to residential traffic was reported by 21.3% of the participants. A high annoyance to traffic and neighborhood noise was associated with a lower equivalised disposable income and poor housing conditions. Additionally annoyance to neighborhood noise was associated with low socioeconomic and occupational status. A high annoyance to aircraft noise was only associated with a low equivalised disposable income and living in apartment blocks. Exposure to residential traffic was associated with all investigated indicators. At present in Germany environmental exposures are social unequally distributed and may lead to negative health consequences in social disadvantaged groups.



**Keywords**

Health survey · Adults · Socioeconomic status · Annoyance to environmental noise · Road traffic intensity



### Soziale Ungleichheit bei Lärmbelästigung und Straßenverkehrsbelastung. Ergebnisse der Studie zur Gesundheit Erwachsener in Deutschland (DEGS1)

**Zusammenfassung**

In der „Studie zur Gesundheit Erwachsener in Deutschland (DEGS1)" wurden die Assoziationen von Lärmbelästigung und Straßenverkehrsbelastung mit soziodemografischen, sozioökonomischen und regionalen Merkmalen sowie mit Wohnverhältnissen an einer bevölkerungsbezogenen Stichprobe von 7988 18- bis 79-Jährigen untersucht. Die Lärmbelästigung und die Straßenverkehrsbelastung wurden mittels Selbstausfüllfragebögen erfasst. Insgesamt gaben 6,3% der Teilnehmer eine starke oder sehr starke Belästigung durch Straßenverkehrslärm, 3,7% durch Nachbarschaftslärm und 2,1% durch Fluglärm an. Eine hohe Straßenverkehrsbelastung wurde von 21,5% der Teilnehmer angegeben. Eine starke Belästigung durch Straßenverkehrs- oder Nachbarschaftslärm war signifikant assoziiert mit einem geringen Netto-Äquivalenzeinkommen und schlechten Wohnverhältnissen. Darüber hinaus war Nachbarschaftslärm mit einem niedrigen Sozial- und Berufsstatus assoziiert. Eine starke Fluglärmbelästigung war nur mit einem geringen Netto-Äquivalenzeinkommen und mit Wohnen in Mehrfamilienhäusern verbunden. Eine starke Belastung durch Straßenverkehr stand mit allen untersuchten Gliederungsmerkmalen im Zusammenhang. Umweltbelastungen sind auch gegenwärtig in Deutschland noch sozial ungleich verteilt und können zu negativen gesundheitlichen Folgen in benachteiligten Bevölkerungsgruppen führen.



**Schlüsselwörter**

Gesundheitssurvey · Erwachsene · Sozioökonomischer Status · Lärmbelästigung · Straßenverkehrsbelastung


## Housing conditions

The answers in the self-completed questionnaire were used to define three categories of building (multifamily house/apartment block/high-rise, detached house/semi-detached house/terraced house and other). Participants aged 64 or younger were asked directly about the ownership status (owned or rented property) of their current home. In the case of participants over the age of 64, ownership status was derived from the answers to the question: Where do you live? With

**Tab. 1** Sociodemographic indicators, socioeconomic indicators and spatial indicators of the DEGS1 study, unweighted case numbers and relative frequencies (results in percent) (Continued)

| Indicator/categories | Cases (n) | Frequency (%) | Frequency (%) |
|---|---|---|---|
| | Unweighted | Unweighted | Weighted |
| **Owned property** | | | |
| Owned property | 4,538 | 56.8 | 55.0 |
| None owned property | 2,945 | 36.9 | 41.5 |
| Other | 255 | 3.2 | 3.5 |
| Missing values | 250 | 3.1 | |
| **Building type** | | | |
| Multifamily house[a] | 2,905 | 36.4 | 39.8 |
| Detached, semi-detached, terraced house | 4,405 | 55.2 | 54.6 |
| Other | 419 | 5.3 | 5.6 |
| Missing values | 259 | 3.2 | |

[a]Including apartment block, high-rise building.

following answering categories: "In my own private household (owner-occupied house, rented apartment, rented house)", "In another private household (of children or relatives, for example)" and "In a nursing home or seniors' residence". There was a further category entitled "other" with a text field for a more detailed description of the dwelling. It was not possible to assign the entries in this text field to any of the ownership categories, however. The subcategories "owned property" and "owner-occupied apartment, own house" were grouped to form the overall "owned property" category. The category "no owned property" included the items "rented apartment, rented house" and "living in a nursing home or seniors' residence". The category "other" remained an independent category which also included the item "living in another private household".

The occupancy rate of the dwelling was determined by dividing the number of rooms (without kitchen, bathroom/WC and storage rooms) to the number of persons living in the dwelling. This rooms-per-capita index [24, 29] was categorized into three categories: up to 1 room per person, >1 to ≤2 rooms per person, and >2 rooms per person.

### Statistical evaluation

The cross-sectional analyses are conducted with a weighting factor which corrects deviations in the sample from the population structure (as of 31 Dec 2010) with regard to age, sex, region, nationality, type of municipality and education [21]. A non-response analysis and a comparison of selected indicators with data from the census statistics indicate a high level of representativity of the net sample for the residential population aged 18–79 years of Germany [21]. To take into account the weighting as well as the correlation of the participants within a community, the confidence intervals and p values were determined using the "survey" package of the statistics program "R" (version 2.12.1) for complex samples [30, 31, 32, 33]. Group differences are considered statistically significant if the respective 95% confidence intervals do not overlap or if the $\chi^2$ test indicated a p value <0.05 based on two-sided tests.

## Results

### Description of study population

Of the 7,988 participants in the DEGS1 survey, 3,790 (49.7%) were men and 4,198 (50.3%) women. The frequency values for further sociodemographic, socioeconomic and spatial indicators of the study population are shown in **Tab. 1**.

### Annoyance to noise

In DEGS1, 37.4% of participants reported strong/extreme annoyance to road traffic noise (**Tab. 2**), with 6.3% even describing road traffic noise as strongly or extremely annoying. Neighbourhood noise was in second place with a frequency of 25.8% and 3.7% of respondents reporting a strong or extreme level of annoyance to this type of noise. The figures for aircraft noise were 17.9% overall, with 2.1% describing annoyance levels as strong or extreme. The rankings continued with playing children, industry/commerce, bars/discotheques and other sources of noise (**Tab. 2**).

### Road traffic noise

Evaluation based on individual indicators showed that there were no statistically significant differences between age groups and sex among participants who complained of strong to extreme annoyance to road traffic noise. And although respondents with low social status reported noise annoyance more frequently than members of the highest status group, but this difference was not statistically significant (**Tab. 3**). This is also the case for the indicators "educational status" and "occupational status", whereas for the equivalised disposable income strata-specific statistically significant differences were found (**Tab. 3**). The results were also statistically significant for the "rooms-per-capita index". Marked statistically significant differences were found with regard to the more "horizontal" indicators of spatial differentiation such as residential region, type of municipality, home ownership and type of building. Even 20 years after reunification, participants in eastern Germany reported strong/extreme annoyance to road traffic noise more frequently than their counterparts in western Germany. Strong to extreme annoyance to noise was also found more frequently in large towns and among residents of rented apartments and multifamily houses, apartment blocks or high-rises (**Tab. 3**).

### Neighbourhood noise

The responses on annoyance to neighbourhood noise show a statistically significant relationship to age, with above all the younger age groups (up to 39 years) reporting strong to extreme annoyance more frequently (**Tab. 3**). There were no differences between men and women. Unlike the findings for road traffic noise,

**Tab. 2** Annoyance to noise and road traffic intensity, unweighted case numbers and weighted frequencies (results in percent)

| Environmental factor/exposure | Cases (n) | Frequency (95% CI)[a] |
|---|---|---|
| | Unweighted | Weighted |
| **Neighbourhood noise** | | |
| Not at all | 5,761 | 74.2 (72.7–75.8) |
| Slight/moderate | 1,646 | 22.1 (20.7–23.5) |
| Strong/extreme | 241 | 3.7 (3.1–4.3) |
| Missing values | 340 | |
| **Road traffic noise** | | |
| Not at all | 4,816 | 62.6 (61.0–64.3) |
| Slight/moderate | 2,350 | 31.1 (29.6–33.6) |
| Strong/extreme | 476 | 6.3 (5.5–7.0) |
| Missing values | 346 | |
| **Aircraft noise** | | |
| Not at all | 6,224 | 82.1 (79.8–84.2) |
| Slight/moderate | 1,189 | 15.8 (13.9–17.8) |
| Strong/extreme | 152 | 2.1 (1.5–2.9) |
| Missing values | 423 | |
| **Industrial/commercial noise** | | |
| Not at all | 6,992 | 92.7 (91.8–93.5) |
| Slight/moderate | 485 | 6.4 (5.6–7.2) |
| Strong/extreme | 79 | 1.0 (0.7–1.3) |
| Missing values | 432 | |
| **Bar/discotheque noise** | | |
| Not at all | 7,036 | 95.2 (94.5–95.8) |
| Slight/moderate | 460 | 4.1 (3.5–4.7) |
| Strong/extreme | 56 | 0.7 (0.5–1.0) |
| Missing values | 436 | |
| **Noise from playing children** | | |
| Not at all | 6,396 | 83.2 (81.9–84.4) |
| Slight/moderate | 1,051 | 15.1 (13.9–16.3) |
| Strong/extreme | 118 | 1.8 (1.4–2.2) |
| Missing values | 423 | |
| **Other noise** | | |
| Not at all | 5,560 | 89.0 (87.8–90.1) |
| Slight/moderate | 628 | 9.1 (8.1–10.2) |
| Strong/extreme | 124 | 1.9 (1.6–2.4) |
| Missing values | 1,773 | |
| **Road traffic intensity** | | |
| Very low | 3,167 | 40.7 (39.0–42.4) |
| Considerable/moderate | 2,951 | 37.8 (36.1–39.5) |
| Extreme/high | 1,590 | 21.5 (20.1–22.9) |
| Missing values | 280 | |

[a]95% confidence interval.

the stratification-specific evaluation of neighbourhood noise exposure showed statistically significant differences based on social status. People in the lowest status group (5.6%) report twice as frequently of strong to extreme annoyance to neighbourhood noise as those in the highest status group (2.6%; **Tab. 3**). Analysis of the three individual dimensions of social status showed statistically significant differences based on equivalised disposable income and occupational status, whereas no such differences were seen based on education (**Tab. 3**). There were also statistically significant stratification-specific differences based on rooms-per-capita index as an indicator for the occupancy rate of a dwelling: participants who lived in dwellings with less than one room per person reported strong to extreme noise annoyance twice as frequently (6.3%) as participants from homes with more than two rooms per person (2.5%; **Tab. 3**). As with road traffic noise, the indicators for spatial differentiation were also strongly associated with the degree of noise annoyance, and the relationships were similar to those with road traffic noise, i.e. more frequent strong to extreme annoyance to noise in large towns, multifamily houses and rented apartments (**Tab. 3**). In contrast to the findings for road traffic noise, there were no statistically significant differences between residential regions (west, east) with regard to annoyance to neighbourhood noise (**Tab. 3**).

## Aircraft noise

The level of annoyance to aircraft noise was associated least of all with the indicator "social status" and its individual dimensions (**Tab. 3**), with only equivalised disposable income showing a borderline statistically significant difference in relative frequencies (3.0% among participants with an income ≤60% of the median versus 1.3% with an income of >150% of the median; **Tab. 3**). A relationship was also observed with the spatial indicators (**Tab. 3**), where there were differences of borderline statistical significance with regard to the indicator "type of building", with residents of multifamily houses reporting strong or extreme annoyance to aircraft noise slightly more frequently than residents of detached, semi-detached or terraced houses (2.7% versus 1.7%). In the case of "type of municipality", there was a steady increase in the relative frequency of strong to extreme annoyance to noise with increasing size of municipality, although this difference was not significant (**Tab. 3**).

## Road traffic intensity at residential address

A total of 21.5% of dwellings were located on very or extremely busy through roads (**Tab. 2**). There was a strong association between the street location of

**Tab. 3** Frequency of strong/extreme annoyance to noise and extreme/high road traffic intensity, stratified according to sociodemographic, socioeconomic and spatial indicators (results in percent)

| Indicator | Road traffic noise | Neighbourhood noise | Aircraft noise | Road traffic intensity |
|---|---|---|---|---|
| | n=7,642 | n=7,648 | n=7,565 | n=7,708 |
| | Frequency (95% CI[b]) | Frequency (95% CI) | Frequency (95% CI) | Frequency (95% CI) |
| **Age group** | | | | |
| 18–29 | 6.1 (4.4–8.2) | 4.9 (3.5–6.8) | 0.9 (0.3–1.9) | 22.8 (19.7–26.1) |
| 30–39 | 5.6 (3.8–8.0) | 5.8 (4.0–8.2) | 2.5 (1.1–4.7) | 21.1 (17.9–24.6) |
| 40–49 | 5.5 (4.3–7.0) | 2.9 (1.9–4.2) | 1.9 (1.2–2.9) | 20.0 (17.4–22.7) |
| 50–59 | 7.5 (6.0–9.3) | 3.4 (2.3–4.8) | 2.4 (1.5–3.5) | 20.0 (17.4–22.7) |
| 60–69 | 6.2 (4.5–8.3) | 2.0 (1.1–3.4) | 2.8 (1.6–4.7) | 21.4 (18.6–24.6) |
| 70–79 | 6.6 (4.8–8.8) | 2.5 (1.4–4.2) | 2.9 (1.6–4.9) | 25.8 (22.4–29.5) |
| p value | 0.4457 | 0.0031 | 0.0016 | 0.0965 |
| **Sex** | | | | |
| Men | 6.6 (5.5–7.8) | 3.6 (2.9–4.5) | 2.3 (1.5–3.4) | 20.6 (18.8–22.4) |
| Women | 5.9 (5.0–6.8) | 3.7 (2.9–4.5) | 2.0 (1.4–2.7) | 22.6 (20.8–24.4) |
| p value | 0.2922 | 0.8983 | 0.5336 | 0.0738 |
| **Social status** | | | | |
| Low | 7.7 (5.8–9.9) | 5.6 (4.1–7.5) | 2.5 (1.5–4.0) | 28.3 (25.1–31.6) |
| Middle | 6.0 (5.2–6.9) | 3.4 (2.7–4.3) | 2.0 (1.4–2.8) | 21.8 (20.2–23.4) |
| High | 5.6 (4.2–7.3) | 2.6 (1.7–3.8) | 2.2 (1.3–3.6) | 14.8 (12.5–17.4) |
| p value | 0.1091 | 0.0008 | 0.7414 | 0.0000 |
| **Equivalised disposable income** | | | | |
| ≤60% median | 8.1 (6.1–10.5) | 6.3 (4.7–8.3) | 3.0 (1.7–4.7) | 25.5 (22.3–28.9) |
| >60%–≤150% median | 5.9 (5.1–6.8) | 3.3 (2.6–4.1) | 2.2 (1.6–2.9) | 22.5 (20.9–24.2) |
| >150% median | 4.4 (3.2–5.8) | 2.4 (1.5–3.5) | 1.3 (0.8–2.2) | 14.7 (12.5–17.2) |
| p value | 0.0019 | 0.0002 | 0.0175 | 0.0000 |
| **Educational status** | | | | |
| Low | 6.1 (5.0–7.4) | 3.7 (2.8–4.8) | 2.3 (1.5–3.5) | 25.2 (23.1–27.4) |
| Middle | 6.2 (5.3–7.3) | 3.8 (3.0–4.8) | 1.8 (1.2–2.7) | 20.5 (18.6–22.4) |
| High | 6.7 (4.9–8.9) | 3.2 (2.0–4.8) | 2.6 (1.4–4.3) | 15.3 (12.3–18.6) |
| p value | 0.6229 | 0.5057 | 0.6946 | 0.0000 |
| **Occupational status** | | | | |
| Low | 6.6 (5.3–8.1) | 4.0 (2.9–5.2) | 2.5 (1.6–3.7) | 25.8 (23.4–28.3) |
| Middle | 6.3 (5.4–7.3) | 3.8 (3.0–4.6) | 2.0 (1.3–2.8) | 20.7 (19.0–22.5) |
| High | 5.0 (3.5–6.9) | 1.9 (1.0–3.3) | 2.2 (1.0–4.0) | 15.5 (12.8–18.5) |
| p value | 0.1537 | 0.0098 | 0.7212 | 0.0000 |
| **Rooms per capita** | | | | |
| Up to 1 room | 8.6 (6.9–10.6) | 6.3 (4.9–8.0) | 1.7 (0.8–3.1) | 25.4 (22.7–28.2) |
| >1–≤2 rooms | 5.7 (4.9–6.7) | 2.8 (2.2–3.7) | 2.3 (1.6–3.2) | 20.3 (18.6–22.1) |
| >2 rooms | 4.8 (3.7–6.2) | 2.5 (1.6–3.6) | 2.2 (1.4–3.3) | 20.0 (17.5–22.7) |
| p value | 0.0005 | 0.0000 | 0.4341 | 0.0031 |
| **Residential region** | | | | |
| West | 5.8 (5.0–6.6) | 3.5 (2.9–4.3) | 2.1 (1.4–3.0) | 20.2 (18.8–21.8) |
| East (including Berlin) | 8.1 (6.3–10.2) | 4.1 (2.9–5.5) | 2.2 (1.2–3.7) | 26.6 (23.8–29.5) |
| p value | 0.0272 | 0.4943 | 0.9273 | 0.0005 |

a dwelling and indicators of social status (**Tab. 3**). A clear and steady trend was recognisable with all investigated social indicators: decreasing social status was associated with an increasing percentage of participants who said they live on busy or extremely busy through roads, with the most marked gradients being recorded according to social status based on its three subscales (lowest status group 28.3%, middle status group 21.8% and highest status group 14.8%). No statistically significant differences were found based on age and sex. The characteristics of spatial stratification were also associated with the road traffic intensity at residential address to a statistically significant degree (**Tab. 3**). This also applied to residential region (west/east). Participants from eastern Germany said more frequently that they live on busy to very busy through roads. There were also clear relationships between the indicators owned property and building type on the one hand and strong to extreme road traffic intensity on the other (**Tab. 3**).

## Discussion

This paper presents the findings of initial descriptive analyses of the DEGS1 study with regard to the frequency of noise annoyance and road traffic intensity in relation to sociodemographic, socioeconomic and spatial indicators.

### Annoyance to noise

Like the findings of other studies before it, the results of DEGS1 show the same ranking of noise sources with regard to the extent and degree of noise annoyance, with road traffic noise as key source, followed by neighbourhood noise and aircraft noise [4, 5, 34, 35, 36]. Beyond this, there are associations of differing degrees between the level of noise annoyance due to various noise sources on the one hand and social status or its subscales on the other. Men and women said with more or less equal frequency that they experienced annoyance to noise to a strong or extreme degree. This finding confirms the results of other studies [24, 37, 38].

### Road traffic noise

In the case of road traffic noise, social status was not associated with strong to extreme noise annoyance to a statistically significant degree, and of the analysed individual dimensions of social status only the subindicator "equivalised

**Tab. 3** Frequency of strong/extreme annoyance to noise and extreme/high road traffic intensity, stratified according to sociodemographic, socioeconomic and spatial indicators (results in percent) (Continued)

| Indicator | Road traffic noise | Neighbourhood noise | Aircraft noise | Road traffic intensity |
|---|---|---|---|---|
| | n=7,642 | n=7,648 | n=7,565 | n=7,708 |
| | Frequency (95% CI[b]) | Frequency (95% CI) | Frequency (95% CI) | Frequency (95% CI) |
| **Type of municipality** | | | | |
| Rural | 4.5 (3.0–6.5) | 2.5 (1.5–3.8) | 1.2 (0.6–2.2) | 23.5 (20.2–27.2) |
| Small town | 6.5 (5.2–8.1) | 2.7 (1.9–3.8) | 1.9 (1.0–3.3) | 21.8 (18.8–25.1) |
| Midsized town | 5.2 (4.2–6.3) | 3.3 (2.4–4.4) | 2.2 (1.3–3.6) | 18.0 (15.7–20.5) |
| Large town | 8.0 (6.5–9.7) | 5.3 (4.1–6.8) | 2.6 (1.4–4.7) | 23.8 (21.5–26.3) |
| **Owned property** | | | | |
| Owned property | 4.7 (4.0–5.6) | 1.8 (1.4–2.4) | 1.9 (1.3–2.5) | 17.2 (15.4–19.1) |
| No owned property | 8.3 (7.0–9.7) | 6.1 (5.0–7.4) | 2.4 (1.4–3.7) | 27.5 (25.3–29.7) |
| Other | 5.4 (2.5–10.0) | 3.1 (1.1–7.0) | 0.4 (0.0–1.8) | 19.8 (13.9–26.8) |
| p value | 0.0000 | 0.0000 | 0.2351 | 0.0000 |
| **Type of building** | | | | |
| Multifamily house[a] | 8.4 (7.2–9.9) | 5.9 (4.8–7.2) | 2.7 (1.8–4.0) | 25.5 (23.4–27.7) |
| Detached, semi-detached, terraced house | 4.5 (3.8–5.3) | 1.9 (1.5–2.4) | 1.7 (1.2–2.4) | 17.6 (15.8–19.6) |
| Other | 8.6 (5.6–12.4) | 5.3 (1.9–11.3) | 2.4 (1.0–4.9) | 33.6 (27.6–40.0) |
| p value | 0.0000 | 0.0000 | 0.0281 | 0.0000 |
| **Road traffic intensity** | | | | |
| Very low | 0.7 (0.4–1.2) | 2.5 (1.8–3.4) | 1.5 (1.0–2.2) | |
| Considerable/moderate | 3.3 (2.5–4.3) | 3.8 (2.9–4.8) | 2.2 (1.2–3.6) | |
| Extreme/high | 21.8 (19.3–24.4) | 5.7 (4.2–7.5) | 3.1 (2.1–4.4) | |
| p value | 0.0000 | 0.0007 | 0.0040 | |

[a]Including apartment block, high-rise building [b]*95% CI* 95% confidence interval.

disposable income" correlated strongly. This finding supports the results of other studies in that all participants from low-income households are more frequently exposed to noise and feel more severely affected by noise [24, 25, 38, 39]. In contrast, other indicators such as educational status or occupational status were less strongly associated with annoyance to road traffic noise [38, 39]. The analysed indicators for spatial differentiation were shown to be of importance: annoyance to road traffic noise is greater in conurbations (large towns) and densely populated areas (multifamily houses) and in housing with low rooms-per-capita index than in rural regions and in less densely populated areas (detached houses or terraced house estates). This finding is in line with the results of the health monitoring units ("Gesundheits-Monitoring-Einheiten", GME) research project in Bavaria [38]. It is also in keeping with the strong observed association between annoyance to road traffic noise and street location of dwellings observed in numerous other studies [25, 35, 37, 38, 39, 40]. Although the differences in annoyance to road traffic noise in western and eastern Germany have decreased over the years, they are still statistically significant two decades after reunification [37, 41]. This finding confirms the results of earlier studies with a similar focus [25, 34] and is possibly due to the persisting deficits in implementing sound abatement measures such as the construction of bypass roads in residential areas in eastern Germany [35]. As with people who live in detached houses, semi-detached houses or terraced houses, the statistically significant lower frequency of noise annoyance among people who own their own homes is to be seen as a function of social status and in particular equivalised disposable income. The wealthier groups of society are better able to locate or settle in residential areas with lower environmental exposures or to move if the environmental exposures in the area in which they live begin to worsen [42].

## Neighbourhood noise

As the results show and as is confirmed by previous studies, neighbourhood noise is meanwhile the second most important source of noise annoyance [4, 5, 37]. In DEGS1, people in the younger age groups (up to 39 years), people of low social status, those from low-income families and people with low occupational status indicate more frequently that they experience annoyance to neighbourhood noise to a strong or extreme degree. This is mainly due to the concrete living situation of these participants. Other studies have shown that people who live in multifamily houses report more annoyance to neighbourhood noise than people from less densely populated residential areas [35]. The findings of this study show that the first group often also comprises younger participants (or families) who live in rented accommodation in multifamily houses with limited space (low rooms-per-capita index). The more frequent responses citing annoyance to neighbourhood noise in areas of high residential density suggest that noise from neighbouring apartments, possibly due to inadequate acoustic insulation in the building, is one of the determining factors for noise annoyance [35].

## Aircraft noise

Compared to annoyance to noise from road traffic or neighbourhood noise, the strong to extreme exposure of participants to aircraft noise appears to be distributed more homogeneously among the indicators used in this study. Statistically significant differences between scores for individual indicators were only found based on the age of participants and one subindicator of social status, namely equivalised disposable income. In contrast to neighbourhood noise, the frequency of strong to extreme annoyance to aircraft noise correlates positively with age, probably due to the fact that older people spend more time at home and are therefore more

likely to experience annoyance to aircraft noise more frequently [43]. Moreover, the main exposure times for aircraft noise appear to be in the early afternoon and evening before the working population generally returns home [44]. Although the figures for type of municipality show a steady numerical trend from strong to extreme annoyance to aircraft noise between rural municipalities at one end and large towns at the other, this trend, though logically plausible (proximity of airports to cities), was not statistically significant.

### Road traffic intensity

Street location of the dwelling is closely associated to the level of exposure of participants to noise from road traffic, and this is why there is strong correlation between the characteristic values for these two indicators. [25, 37, 38, 39, 45]. Compared to the results for annoyance to road traffic noise, the gradient between high road traffic intensity (street location of the dwelling) and all socioeconomic stratification indicators evaluated in this study is consistently more marked and highly significant. As high road traffic intensity is also associated with higher exposure to particulate matter and exhaust fumes, this constellation results in a situation where members of the low status group are exposed not only to increased noise burdens but also to higher pollution levels, i.e. to multiple exposures. The study of school beginners in Saxony-Anhalt, for example, showed that children from families with high social status lived more frequently in dwellings with lower exposure to traffic emissions than children from socially disadvantaged families. The key factor in this regard was not so much educational background but the occupation of the parents. By the same token, children from socially disadvantaged families lived closer to busy roads than children from families of higher social status [46].

## Conclusion

**Environmental exposures are still inequitably distributed among different groups in German society, and this can in turn result in unequally distributed adverse health impacts within the population. The most severe effects are suffered by people who live in low-income households and whose limited financial resources mean that they can often only afford housing that is highly exposed to environmental burdens. The complex distribution of these environmental exposures is reflected by the fact that the study found not only vertical stratification patterns based on socioeconomic characteristics but also spatial-geographic patterns (horizontal patterns) based on housing conditions. Future studies should incorporate both stratification indicators to a greater extent in order to permit more in-depth analysis of the distribution of environmental exposures. Moreover, these studies should aim to extend the scope of investigation by including indicators that record the life attitudes and lifestyles of study participants, paving the way for more accurate characterisation of the social complexity of perceived environmental exposures. This could make a key contribution towards improving environment-related health protection among the population.**

**One limitation of the study is that the evaluation is based on exclusively subjective assessments of environmental exposures. Future studies should attempt to supplement the details provided by study participants by conducting independent measurements and on-site inspections.**


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