Are Primary School Students Exposed to Higher Noise Levels than Secondary School Students in Germany?

M Bhardwaj, U Baum, I Markevych, A Mohamed, T Weinmann, D Nowak, K Radon

Abstract

Background: Noise, one of the major environmental nuisances, affects the learning ability of children negatively.

Objective: With the assumption that in the existing German 4-type school system children are exposed to various noise levels in each type of school, we investigated the association between children’s school type and environmental noise level.

Methods: In this cross-sectional study, we included 550 children—primary and secondary school students—aged 8–12 years, and who lived in 4 Bavarian cities. The environmental noise level was assessed by personal 24-h dosimeter measurements. The associations of interest were assessed by linear regression.

Results: The average day noise level of 80.0 dB(A) was relatively high, exceeding the threshold level of 60 dB(A). In the model adjusted for sex, socioeconomic status (SES), and place of residence, noise level was significantly higher for primary schools by almost 2.3 dB(A); however, after additional adjustments for age, this association was distorted. The mean night noise level of 43.7 dB(A) was not associated with the school level. We could not find any significant differences in the noise level between different types of secondary schools.

Conclusion: We found evidence that in Germany, children, especially of a younger age from primary school, are exposed to high noise levels during day in and outside the school environment. School administration and parents should work to make schools less noisy and more accomplished for learning to achieve a bright future for the children.

Keywords: Noise; Schools; Child; Learning

Introduction

Noise, a ubiquitous environmental pollutant, is an important public health issue because it leads to annoyance, reduces environmental quality and affects health. Indiscriminate filtering of noise and noise annoyance have been two of several suggested pathways of association between chronic noise ex-
3336 persons from 4 Bavarian cities were randomly selected and invited to the study.

1742 persons participated in the 24-h noise dosimeter measurements.

- 628 children (aged 8-12)
- 632 adolescents (aged 13-17)
- 482 adults (aged 18-65)

70 children were excluded due to missings.
8 children were excluded due to studying in uncommon types of schools.
550 children were included into the analysis.

**Figure 1:** Sampling of the participants for the LEe-Noise study (2005–2006, Bavaria, Germany) and the participants enrolled into the current analysis.

Exposure and children’s cognition. Attention, memory and reading are all involved in cognitive development in initial years of life from age 5–11 years. Children are particularly vulnerable to the effects of noise because noise can potentially interfere with learning at a critical developmental stage in children and because they have less capacity than adults to anticipate, understand and cope with stressors.

During the last three decades, more than two dozen studies have shown that chronic exposure to environmental noise such as rail-, road- and air-traffic would negatively affect children’s learning, reading and memorizing abilities, and psychological and cardiovascular health. Most of these studies have focused on the effects of one of these external noise sources, although exposure to noise in the classroom is likely to be a combination of internal as well as external sources. The internal sources of noise like air conditioners, overhead projectors, computers and documenting cameras, children’s own noise, etc, however, cannot be neglected. Therefore, summative assessment of environmental noise regardless of the source is of utmost importance.

Much of children’s learning occurs at school that makes school one of the most
important micro-environments for children. And, that is why noise exposure at school is most pertinent to influence a child’s cognitive performance and behavior. Moreover, in Germany, children attending primary school often live quite close to their school and thus their environmental noise exposure at school and at home should be almost similar. In many of recent studies, noise exposure has been selected on the basis of the school which children attend. However, none of these studies laid an emphasis on studying the association between the types of school and environmental noise levels. If an association between the type of school and high noise level existed, the sources of such noise and the groups of children more prone to be affected by such noise could be identified. Having identified such facts, it would be easier to plan and implement guidelines to encounter these problems.

The German school system comprises several school types. In Bavaria, the most common types are Grundschule covering primary education and Hauptschule, Realschule, and Gymnasium covering secondary education. The objective of the current study was to investigate whether noise exposure differs for children aged 8–12 years that study in different types and levels of schools. Data were collected within a cross-sectional study in Bavaria, southeastern Germany, during 2005–2006.

Materials and Methods

Study design and study population

The analyses were based on data collected between 2005 and 2006 within the cross-sectional LEe-Noise study. This study was conducted in four Bavarian cities—Munich (population 1,350,000), Ebersberg (population 110,000), Freising (population 450,000) and Grafing (population 130,000)—and investigated the association between noise exposure and well-being. A detailed description of the study methods and instruments has

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>n (%) or mean±SD</th>
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<tbody>
<tr>
<td>Sex</td>
<td></td>
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<tr>
<td>male</td>
<td>288 (52.4)</td>
</tr>
<tr>
<td>female</td>
<td>262 (47.6)</td>
</tr>
<tr>
<td>Age (yrs)</td>
<td>9.9±1.3</td>
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<tr>
<td>School type</td>
<td></td>
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<tr>
<td>Grundschule</td>
<td>314 (57.1)</td>
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<tr>
<td>Hauptschule</td>
<td>42 (7.6)</td>
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<tr>
<td>Realschule</td>
<td>56 (10.2)</td>
</tr>
<tr>
<td>Gymnasium</td>
<td>138 (25.1)</td>
</tr>
<tr>
<td>Residence</td>
<td></td>
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<tr>
<td>Munich</td>
<td>127 (23.1)</td>
</tr>
<tr>
<td>Ebersberg</td>
<td>166 (30.2)</td>
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<tr>
<td>Freising</td>
<td>173 (31.5)</td>
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<tr>
<td>Grafing</td>
<td>84 (15.3)</td>
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<td>Socio-economic status</td>
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<tr>
<td>low</td>
<td>57 (10.4)</td>
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<tr>
<td>medium</td>
<td>263 (47.8)</td>
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<tr>
<td>high</td>
<td>230 (41.8)</td>
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<td>Noise level (dB(A))</td>
<td></td>
</tr>
<tr>
<td>day</td>
<td>79.7±5.8</td>
</tr>
<tr>
<td>night</td>
<td>43.7±6.8</td>
</tr>
</tbody>
</table>

Table 1: Socio-demographic characteristics of the study participants and diurnal environmental noise level measurements among them, LEe-Noise study, 2005–2006, Bavaria, Germany (n=550)
been given elsewhere.\textsuperscript{31} In the current analysis, the study population comprised children aged 8–12 years. Study subjects were randomly selected from the population registries of the respective cities and asked to participate through a postal invitation. A parents' signed agreement was necessary for the children's participation. Of the 1030 children invited to the study, 628 participated in 24-h dosimeter measurements and responded to a questionnaire (response rate 61%). Due to missing values in the questionnaire or in the dosimeter measurements, 70 children were excluded to allow a complete case analysis. Of the remaining 558 study subjects, eight reported uncommon school types and were eliminated from the data set. Finally, 550 children were included in the analyses (Fig 1).

Questionnaire and special items

All participants answered a questionnaire in a computer-assisted personal interview.\textsuperscript{32} The questionnaire asked for individual characteristics of the study subjects like sex, age, place of residence, and type of the current school. Additionally, occupational characteristics of the parents, which determine the socioeconomic status (SES) of the children, were assessed by the questionnaire. We considered three SES indicators: parental level of education, parental occupational position, and per-person household income, following the strategy of Lange, \textit{et al}, in the KiGGS study.\textsuperscript{33} Each indicator was categorized into five groups and scored with one point for the “lowest” and up to five points for the “highest” category. The sum of the scores was an index of the SES. Index values from 3 to 6, from 7 to 10, and from 11 to 15 were categorized as “low,” “middle,” and “high SES,” respectively. SES was assessed separately for both of the parents. If there were differences between SES of the parents (including the case that SES of one of the parents was missing), their child was assigned to the higher (available) status.

Outcome definition: the environmental noise level

The study subjects individual exposure to environmental noise was examined with personal dosimetry measurements, explained in detail by Weinmann, \textit{et al}.\textsuperscript{31} The participants carried the dosimeter for 24 h and were instructed to follow their usual activities. The dosimeter recorded the noise level (unit: dB(A)), the biophysically weighted sound pressure level,\textsuperscript{34} in the environment of the study subject. These records were summarized and transformed into two variables—the mean individual noise level during the day and during the night. The individual's day and night time were based on the 24-h records and self-reported sleeping hours.\textsuperscript{31}

Ethics

The study has been approved by the appropriate ethics committee and has therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

Statistical analysis

We performed bivariate analyses of diurnal environmental noise level, including Kruskal-Wallis rank sum tests. Multiple linear regression models were used to investigate whether the type or the education level of the current school is associated with the current environmental noise level. As predictor, we entered the school type or the school level in our crude models. First, we adjusted our models for the potential confounders—sex, SES, and place of residence. Second, age was added as a further confounding variable to the adjustment. To analyze differences between the secondary school types in more
In detail, we restricted the study population in a separate model to secondary school students and repeated the analyses. As sensitivity analysis, we compared the socio-demographic characteristics of the 550 included and 78 excluded study participants by using Kruskal-Wallis rank sum test and χ² test. All statistical analyses were conducted with R 2.14.1.

**Results**

Socio-demographic characteristics of the study participants and their levels of environmental noise exposure are given in Table 1. The mean±SD age of the study participants was 9.9±1.3 (range: 8–12) years. Of 550 children included in the current analyses, 52% were boys; 57% were girls.
studying in primary schools, the rest were in secondary schools of different types, mostly in Gymnasium; 23% lived in Munich, the others lived in three smaller cities. Vast majority of the children had medium or high SES. Seventy-eight excluded study participants were statistically significantly older (mean±SD age of 10.2±1.1 years) but they did not differ in other socio-demographic characteristics from those included in the analyses (data not shown). The average diurnal noise level among the study participants was relatively high. The mean noise level during the day was 80 dB(A); the mean noise level during the night was 44 dB(A).

Children’s diurnal noise levels stratified by their socio-demographic characteristics are given in Table 2. The noise exposure levels during the day were on average higher for those children who were studying in primary schools compared to secondary schools and for boys compared to girls. The noise exposure levels during the day were independent of the place of residence or SES. The noise exposure levels during the night were higher for the Munich residents compared to the residents of the cities with smaller populations. They were independent of other investigated socio-demographic characteristics.

According to the results of the model that compared different types of schools with Grundschule (Table 3), noise levels were significantly lower for Realschule and Gymnasium (by around 2.4 dB(A) for both) but not for Hauptschule. The model also showed that noise levels were significantly lower for secondary than primary schools by around 2.3 dB(A) (Table 3). After adjustment for sex, place of residence and SES, these associations remained consistent for both models and even slightly strengthened and became statistically significant for Hauptschule. When

| Table 3: Linear regression analysis for the associations between study participants’ diurnal environmental noise level and school type and level, LEe-Noise study, 2005–2006, Bavaria, Germany (n=550) |
| Day | Night |
| Adjusted estimates 1 | Adjusted estimates 2 | Adjusted estimates 1 | Adjusted estimates 2 |
| β (95% CI) | β (95% CI) | β (95% CI) | β (95% CI) |
| School type (ref. Grundschule) |
| Hauptschule | -2.01 (-3.84 to -0.18) | -0.58 (-2.82 to 1.65) | -0.09 (-2.28 to 2.09) | -0.14 (-2.83 to 2.55) |
| Realschule | -2.32 (-3.93 to -0.72) | -0.77 (-2.90 to 1.36) | -0.12 (-2.04 to 1.80) | -0.17 (-2.73 to 2.39) |
| Gymnasium | -2.42 (-3.56 to -1.29) | -0.95 (-2.70 to 0.81) | -0.26 (-1.61 to 1.10) | -0.31 (-2.41 to 1.80) |
| School level (ref. primary school) |
| secondary school | -2.33 (-3.27 to -1.38) | -0.84 (-2.48 to 0.80) | -1.68 (-1.32 to 0.93) | -1.25 (-2.21 to 1.73) |

Adjusted estimates 1—models adjusted for sex, place of residence and socio-economic status; adjusted estimates 2—models adjusted for sex, place of residence, socio-economic status and age.

β: Estimated regression coefficients; CI: Confidence interval.
we adjusted both models additionally for age, the identified associations disappeared (Table 3). We did not observe any statistically significant associations between noise exposure levels during the night and type or level of school (Table 3). After restricting the study population to only 236 secondary schools’ children, no statistically significant difference between three types of secondary schools was found (data not shown).

Discussion

Our study aimed to find a possible association between the children’s type of school and the environmental noise level. The mean noise level during the day was found to exceed the threshold value of 60 dB(A) for adverse health effects; the mean noise level during the night was also relatively high. The study demonstrated that primary school students were exposed to higher noise levels during the day compared with secondary school students. However, it was not possible to confirm any causal relationship because of the cross-sectional study design and the confounding effect of age. Probably, the higher noise level during the day for primary school students was caused mainly by their younger age. Mean noise levels did not differ between three types of secondary schools.

So far, there are only a few studies considering objective noise level measurements by personal dosimetry. This method of dosimetry is recommended by the European Union Environmental Noise Directive 2002/49/EC. It enables the summative assessment of environmental noise levels independently of the source. Taking into account that our study required personal measurements with dosimeter, the response rate was considerably high. So, the study is not likely affected by selection bias as it was population-based with an acceptable response rate. The sample size was sufficient as a whole and in the categories of individual school levels and types. Consequently, the statistical power was maintained while performing multiple linear regressions. The main results of the study should be generalizable to Germany since the school systems are similar, comprising primary and secondary schools. The generalizability of this analysis to Europe is questionable on account of major differences in the educational systems.

Because the duration of the measurements was limited to only 24 h, there is a possibility that the individual noise levels assessed in this study might not be representative for the subjects’ noise exposure over a longer period. Multiple measurements on more than one day could have been chosen to increase the reliability of our study. The dosimeter on the other hand, measured a general environmental noise level. Neither could the device differentiate different sources of noise nor could it differentiate desirable sound

TAKE-HOME MESSAGE

- Numerous epidemiological studies have found negative effects of long-term exposure to traffic noise on cognition and learning abilities among primary school children.
- Children in southeastern Germany are exposed to high noise levels during the day.
- Primary school students were exposed to higher noise levels during the day compared with secondary school students.
- We could not find differences in the noise level between the different secondary school types.
from undesirable one. As the device was unable to distinguish between the environmental noise and subject’s own voice, the bias due to non-differential misclassification could not be avoided. In order to overcome this flaw and to evaluate mainly the noise exposure in school premises the questionnaire could have included some items to quantify the time each child spent in school on the measurement day. Also, threshold values of adverse health effects are based on studies considering adults. Since children are noisier than adults and likely more susceptible to noise, application of threshold values should be treated with caution.

Further analyses in the future are essential due to the limited number of available studies on this topic. Though there are not many studies that reflect the noise level within the classroom, results from a Finnish study show that children are exposed to noise levels around 70 dB within the classroom. Apart from laying emphasis on reducing external environmental noise, noise from within the classroom or the school building should also be considered and reduced. Since children in primary schools are noisier compared to those in secondary schools, the number of children per classroom should be lowered in primary schools. As many studies showed, the environmental noise is associated with cognitive problems in children; general awareness is needed among school administrations and parents regarding the noise levels in (especially primary) schools in order to make necessary precautions for more successful learning process to achieve a bright future of the children.

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**Conflicts of Interest:** None declared.

**References**

Exposure of School Children to Noise in Germany


