Noise exposure and health effects in children: Results from a contextual soundscape perspective

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Introduction

Empirical research on noise health impacts has focused mainly on direct effects and often reported inconsistent results – especially in studies with children[1][2]. It is well known that children are more dependent on the surrounding environment since they are not able to make their own choices. Since, human reactions to physical environmental conditions occur within a social and ecological context that shapes their responses it is necessary to adapt the research frame[3][4]. In a contextualized perspective the potential direct effects of noise can be moderated by individual, social, housing and neighbourhood factors in both directions (attenuation and aggravation). It seems obvious - when these moderating factors are neglected - environmental health impact assessments may be wrong or we miss relevant factors which are possible targets for prevention[5][6].

This paper presents deepened analyses from two studies on children in two alpine valleys exposed to transportation noise from a major transit traffic route (road and rail noise).

Methods

Study I

Area and sample: In a cross-sectional study 1310 schoolchildren (3rd+4th grade) from 49 schools in the Wipptal around the Brenner Pass were approached (response = 85.5%). The children survey utilized an extended environmental list (28 items) to gather information on perception/annoyance/disturbance and personal living area assessment with Likert-type verbal scale (4 grades). In addition cognitive and psychological functioning, QoL (KINDL), reading (Salzburger Lesetest), blood pressure, BMI, urine cortisol, lung functions and sleep quality was assessed. Information on socio-demographic data, housing, children‘s activities and environment, children‘s dispositions, peri-natal data, sleep, children‘s health and medications were obtained from each child’s mother. **Sound exposure:** The main sound exposure resulted from road (motorway, main and local roads) and rail traffic. Road emissions were calculated with an early version of the Harmonoise source model[7] supplemented with additional traffic counting and micro-simulations of the traffic flow (Paramics). Railway noise emission was extracted from a typical day out of several long-term sound immission measurements near the source (25 m). Sound modelling was carried out with Bass3, an extended version of ISO9613. The model includes up to four reflections and two sideway diffractions[8][9]. The validity of these simulations was calibrated against measurement results from extensive sound monitoring campaigns during summer and winter. Indicators of day, evening, night exposure and Lden were calculated for each sound source and total exposure for all facades of the participant’s home. Lden at the most exposed façade was used in the present analyses and assigned by GIS-linking. Exposure range was between 30 to 80 dBA,Lden. 14.7 % of the sample was exposed above 65 dBA,Lden and 29.5% between 55 and 65 dBA,Lden. **Statistical procedures:** The various outcome models were based on multiple logistic regression techniques[10] with successive adjustment of potential risk or preventive factors based on literature reviews.

Study II

Area and sample: A large cross-sectional study was carried out in the lower Inn valley (Tyrol) among schoolchildren from 26 schools (N= 1280, response = 79.5%). The children answered an environmental list (19 items) which gathered information on perception/annoyance/disturbance and personal living area assessment with a Likert-type verbal scale (4 grades). Socio-demographics, as well as biological risk information were collected from each child’s mother. Pre- and peri-natal data were assessed from doctor’s entries in the “mother-child-passports”. Further biological, social, and environmental data were collected with a self-administered, standardised questionnaire from both the mother and the children. A 22 item scale, Health Related Quality of Life (HRQoL), was construced from two sub-scales of the KINDL[11] and four items on a sleep disturbance scale (Cronbach’s α=0.87) to create an overall assessment of children’s health related quality of life. **Subsample:** From this representative study a smaller sample of children (N = 115) was collected for a more detailed multi-method study (“trailer study”). Through a GIS-link a two-step stratified sampling was conducted. In the first step children were sampled from the extremes of the noise exposure distribution (< 50 dBA,Ldn versus > 60 dBA,Ldn). In the second step children were randomly selected and assigned to the low or high noise group by the educational status of their mothers. Participation in the trailer study was lower (64%) – but the trailer sample did not differ significantly on various social, lifestyle, and biological factors from the larger study. In this subsample more extensive measurements were carried out under highly controlled conditions. Overnight urine (8-h) was collected with the assistance of the child’s mother. Cortisol and 20a-dihydrocortisol in urine were used as indicators of chronic stress[12]. Resting blood pressure was measured by two

trained investigators in a climate controlled and sound attenuated (Leq <35 dBA) mobile trailer. Further assessments were done on reading, memory tasks and annoyance ratings of originally recorded sound from rail and road traffic of the living areas.
Sound exposure: The motorway, intensive nightly rail traffic main, and local roads were the significant sound sources. Modeling was conducted with Soundplan® according to the Austrian guidelines ÖAL Nr 28+30 and ÖNORM S 5011. Calibration and correction was based on day and night recordings from 31 measuring sites. Linear corrections were applied to the modeled data when the difference to the measured data exceeded 2 dB. Approximate day-night levels (dBA,Ldn) were calculated for each child's home.
Statistical procedures: In the modeling of the exposure-effect relationships, multiple logistic regression techniques and restricted splines were applied to account for non-linearity in selected predictors[10]. The models were built up in several steps. First, a model with standard risk factors was established. Environmental and housing factors and sound levels were entered in a second step. In the third step potentially effect modifying factors were evaluated. Final validation and was done by bootstrapping elimination of redundant factors followed against multiple discrimination criteria. The final model was penalized to account for the potential risk of overfitting in relatively small data sets[13].

Results

Study I

Sound exposure and disturbance: In this study 44.2% of children were exposed to total sound levels higher than 55 dBA,Lden. 14.7% of these had exposure above 55 dBA,Lden. On the perception side cars were heard most often – in the southern Wipp-valley it was train noise. Between 8.6 and 12.1% of children felt highly annoyed by noise from cars and between 5.1 and 9.4% by trucks noise. Train noise was the source of high annoyance for 6 to 10.8% of children. In terms of interference with activities difficulties to fall asleep did show the highest prevalence. Interestingly, this percentage did not differ from the prevalence found in the side valley, where significantly lower Lden-levels were observed.
In the statistical model total sound exposure was significantly associated with high annoyance after full adjustment of cofactors.

Sound exposure and cognitive functioning: The digit span testing for short-term memory did reveal a significant negative effect of total sound exposure in the full model. The effect was based mainly on road traffic sound exposure. Train noise was no longer significant in the fully adjusted model. Note: the effect of the total sound exposure was in the same order of the effect of educational attainment of the child’s mother. The traffic perception indicator was also a significant parameter in the final model and children with a quiet room did show better results.

Sound exposure and reading:

The result of the reading test was not significantly linked with total sound exposure. The traffic perception indicator did show a stable significant relation with the reading score. Children having a quiet room at their disposition exhibited higher reading scores than those without.

Sound exposure and sleeping:

The relation of the total sound exposure with the sleep quality indicator was only significant in the base model – but not when traffic perception was accounted for in the model – which was the strongest contribution overall. The availability of a quiet room for the child had a positive effect on overall sleep quality.

Sound exposure and health related well-being:

The total sound exposure was not significantly related to a health related quality of life index in a fully adjusted model. The index of subjective perception of the traffic, however, shows a stable and significant negative association with both the physical and psychological subscale of the health related quality of life index. The option to retreat in a quiet room shows a positive association with HRQoL. Impaired sleep quality is the largest contributor in the fully adjusted model.

Study II

Sample and sound exposure distribution: the stratified random sampling was quite successful. The two samples did not differ significantly in the main background variables: education, sex, BMI, height, family history of hypertension and housing. The exposure sampling strategy to separate the children of the two samples sufficiently from each other was also achieved (Figure 1).

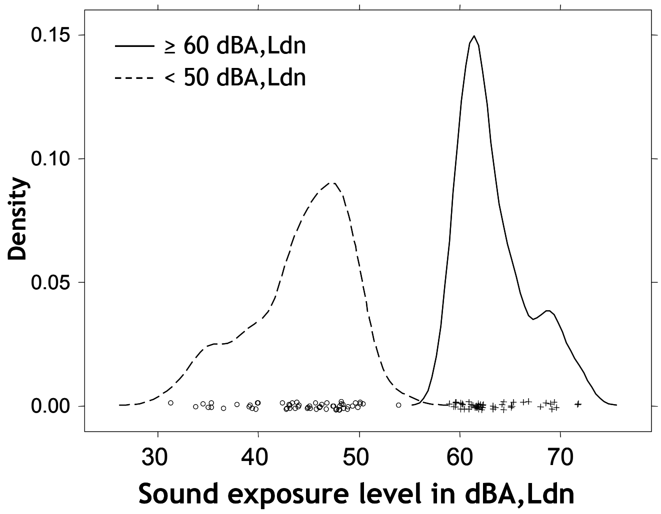

Figure 1. Total sound exposure level distribution in the two subsamples

Systolic blood pressure (SBP): The variance explained of the final penalized SBP-model was high (adjusted R^2 = 0.42). The strongest predictors were in this order: family history of hypertension, living in a multiple apartment versus single detached home, body mass index, rating of living area as quiet, male sex, maternal education. Both annoyance indicators (rail and road) were no longer significant in the presence of the “area is quiet” rating. Neither the sign nor the coefficient size changed in the presence of the two annoyance ratings. Inclusion of air pollution (NO2 as indicator) did not change the result. Since the sound level interacted with short gestational age and with urine overnight cortisol excretion no main effect size is reported. However, you can derive the approximate mean size of the interaction effect with short gestation (<37 weeks) by comparing the difference in SBP in the low and high exposure group.

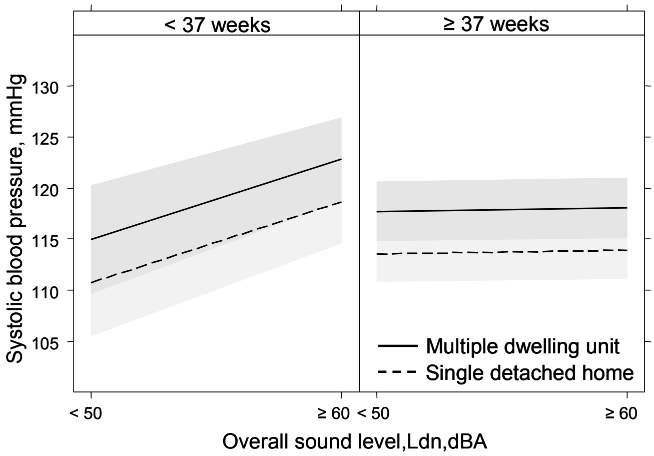

Figure 2. The effect of housing on systolic blood pressure, adjusted for sex, education, family history of hypertension, BMI, area quiet, sound*gestation and sound*cortisol

Note: the effect size of housing is in the same order like an inter-quartile range of BMI or lower educational status of the child's mother.

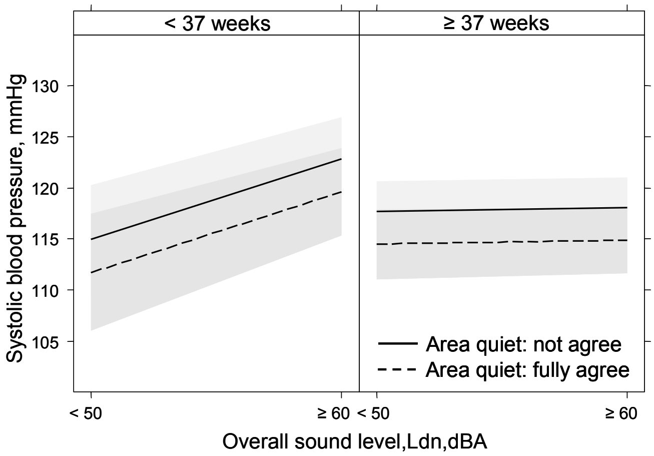

Figure 3. The effect of rating the area as quiet on systolic blood pressure, adjusted for sex, education, family history of hypertension, BMI, housing, sound*gestation and sound*cortisol

Although the effect size of rating the area as quiet is slightly smaller than the effect of housing the stability of the positive effect in the presence of relevant physical factors such as sex, BMI, family history and gestation length is remarkable. The effect of air pollution (NO2) was negative and did not indicate in the expected direction – but there was no change in the final model by the exclusion of this factor after bootstrapping and penalizing the final model. The diastolic blood pressure model was completely dominated by the BMI. This was the only significant and stable effect.

Summary and discussion

Study I: The large representative study revealed three important findings. First, sound exposure levels showed a significant positive relation with annoyance and a negative one with short-term memory. Secondly, a summary indicator of the subjective perception of traffic noise impairments was negatively associated with sleep quality, reading achievement, short-term memory and quality of life. These findings remained unchanged after adjustment for a host of relevant cofactors including sound exposure levels. Thirdly, in the same adjusted model, the availability of a quiet room - to retreat from disturbing sound exposure - exhibited a positive effect on sleep quality, reading achievement, short-term memory, annoyance and quality of life. Although it is well known that most children profit from quiet conditions in the classroom[14] it is new that a wider benefit may be gained by having a quiet room at home at their disposition.

Study II: This smaller sub-study found that ambient community levels of transportation noise have a significant impact on children's systolic blood pressure, especially, when these children show higher vulnerability as indicated by shorter gestational age and by higher cortisol excretion during night. Beyond these interactions with noise environmental factors like living in a multi-dwelling housing unit showed a significant negative impact on SBP. Apart from the sound level the rating of the immediate living area as quiet remained as independent positive factor on SPB-readings. While short gestation was negatively associated with SBP in a Dutch children's study – the effect was smaller, not significant and interaction with noise was not evaluated[15]. The negative effect of apartment housing on blood pressure has been observed hitherto only inconsistently in adult studies[16][17] and is difficult to understand – since education was adjusted for in our study and density not a significant factor in the final model. In an earlier study we found children reporting higher annoyance in apartment homes[18]. The finding of the "area is quiet" ratings of children as a potential buffer effect against blood pressure in the presence of an interaction between noise and short gestation is new. Soundscape indicators were related mostly to subjective indicators of health. Importantly, the result remained stable when both annoyance indicators were in the model. The cross-sectional design of the study prohibits a causal interpretation and the small sample requires replication of the study. A strength of the study was the measurement of blood pressure under controlled conditions in a sound attenuated trailer by only two well trained investigators and the stratified random sub-sampling from a large representative survey.

Conclusions

The two studies demonstrate that sound exposure indices alone are not sufficient to detect all adverse cognitive, psychological and health effects. Instead the subjective perception was more consistently related with these negative health indicators than the sound level. On the other hand the availability of a quiet room was associated with a small reduction of systolic blood pressure while living in an apartment was associated with higher blood pressure. This indicates that a contextually oriented soundscape perspective allows a broader assessment and uncovers a wider preventive perspective to avert adverse effects due to noise. Improving the environmental quality of the home and near-home environment seems a promising approach[19][20].

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