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Exposure to road traffic noise and children's behavioural problems and sleep disturbance: Results from the GINIplus and LISAplus studies

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ABSTRACT

Background: Exposure to transportation noise showed negative health effects in children and adults. Studies in children mainly focussed on aircraft noise at school.
Objectives: We aimed to investigate road traffic noise exposure at home and children's behavioural problems and sleeping problems.
Methods: 872 10-year-old children from Munich from two German population-based, birth-cohort studies with data on modelled façade noise levels at home and behavioural problems were included. Noise was assessed by the day–evening–night noise indicator L_{den} and the night noise indicator L_{night}. Behavioural problems were assessed by the Strengths and Difficulties Questionnaire (SDQ). A subgroup ($N=287$) had information on sleeping problems. Continuation ratio models (logistic regression models) adjusted for various covariates were applied to investigate the association between interquartile range increases in noise and SDQ scales (sleeping problems).
Results: Noise measured by L_{den} at the most exposed façade of the building was related to more hyperactivity/inattention (continuation odds ratio (cOR)=1.28(95%-confidence interval(CI):1.03–1.58). Noise at the least exposed façade increased the relative odds for having borderline or abnormal values on the emotional symptoms scale, especially the relative odds to have abnormal values for a subject with at least borderline values (L_{den}:cOR=2.19(95% CI:1.32–3.64). Results for L_{night} were similar. Nocturnal noise at the least exposed façade was associated with any sleeping problems (odds ratio (OR)=1.79(95% CI=1.10–2.92)).
Conclusions: Road traffic noise exposure at home may be related to increased hyperactivity and more emotional symptoms in children. Future longitudinal studies are required to explore noise exposure and behavioural problems in more detail, especially the role of sleep disturbances.

1. Introduction

Exposure to transportation noise from aircraft, road traffic or trains showed negative health effects in adults and children (Clark and Stansfeld, 2007; WHO, 2009; WHO, 2011). In children, most studies to date focussed on investigating the effects of exposure to aircraft noise. Consistent results were found for impaired cognitive function such as reading comprehension and recognition memory in children exposed to aircraft noise at school (Stansfeld et al., 2010, 2005). Increased blood pressure (Paunovic et al., 2011) and annoyance reactions (van Kempen et al., 2009) were also reported to be associated with children's exposure to noise. However, the results for the association between noise exposure and children's psychological well-being were partly inconsistent. Some studies investigating the effect of exposure to aviation noise reported no association with children's mental health or depression and anxiety symptoms (Haines et al., 2001b, 2001c; Stansfeld et al., 2005). In contrast, Evans et al. (1995) reported that children living in aircraft-exposed

Abbreviations: SDQ, strengths and difficulties questionnaire; OR, odds ratio; cOR, continuation odds ratio; CI, confidence interval; L_{den}, day–evening–night equivalent noise level; L_{night}, night equivalent noise level; max(L_{den}), L_{den} at the most exposed façade of the children's home address; min(L_{den}), L_{den} at the least exposed façade of the children's home address; max(L_{night}), L_{night} at the most exposed façade of the children's home address; min(L_{night}), L_{night} at the least exposed façade of the children's home address

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communities showed lower levels of psychological well-being measured by a quality of life measurement instrument. Lercher et al. (2002) reported that exposure to noise (combined noise indicator for rail and road traffic) at home was significantly associated with an impairment of children's self-reported mental health but only in a subgroup of children who were either born preterm or had a low birth weight. In The West London Schools Study, Haines et al. (2001a) observed a weak association between aircraft noise at school and hyperactivity/inattention scores of the Strengths and Difficulties Questionnaire (SDQ). The Road Traffic and Aircraft Noise Exposure and Children's Cognition and Health (RANCH) study, a cross-national study around three large European airports, found no association between either daytime exposure to aircraft or road traffic noise at school and children's overall mental health measured by the total difficulties score of the SDQ (Stansfeld et al., 2005). However, significant associations between transportation noise and scores on the subscales of the SDQ were observed: Exposure to aviation noise was associated with higher hyperactivity/inattention scores and road traffic noise showed lower values for conduct problems (Stansfeld et al., 2009). In the London subgroup of the RANCH study population, nocturnal exposure to aircraft noise at home did not affect children's mental health, neither on the total difficulties score of the SDQ nor on any of its subscales (Stansfeld et al., 2010). Due to the results of Lercher et al. (2002), Crombie et al. (2011) investigated the potential modification of the association between noise exposure at school and children's mental health by early biological risk (born prematurely or low birth weight) in the RANCH study. Associations between aircraft noise exposure at school and higher values on the hyperactivity/inattention scale and road traffic noise and decreased conduct problems scores were observed. Whereas the latter association withstood the adjustment for early biological risk, the former did not.

The aim of the present study was to provide further insight into the effects of noise exposure on children's psychological well-being focussing on road traffic noise exposure at home. In a subgroup, the association between exposure to nocturnal noise and sleeping problems was investigated.

2. Material and methods

2.1. Study population

The Influence of Life-style factors on the development of the Immune System and Allergies in East and West Germany Plus the influence of traffic emissions and genetics (LISAplus) and the German Infant Study on the influence of Nutrition Intervention Plus environmental and genetic influences on allergy development (GINIplus) are ongoing population-based birth-cohort studies.

For LISAplus, the parents of neonates admitted to maternity hospitals in four German cities (Munich, Leipzig, Wesel and Bad Honnef) were contacted for participation in the study. A total of 3097 healthy, full-term neonates were recruited in the study between December, 1997 and January, 1999. Screening, recruitment and exclusion criteria were described for example by Heinrich et al. (2002) and Zutavern et al. (2006).

The GINIplus study aimed to study the influence of nutrition intervention in infancy, environmental exposures and genetic factors on the development of allergies. Between September, 1995 and June, 1998, a total of 5991 healthy, full-term infants born in Munich and Wesel, Germany, were recruited in the GINIplus study. The study population consists of an interventional and an observational group. Children with family history of allergy were assigned to the intervention group and the observational subgroup comprises children who either have a negative family history of allergy or have a family history of allergy but whose parents did not give consent for participation in the intervention trial. A description of the study design has been published previously (von Berg et al., 2010). The LISAplus and GINIplus studies were approved by the local ethics committees and written consent was obtained from the parents of all study participants.

Inclusion criteria for the current study were participation at the 10-year follow-up, the availability of noise exposure data (home address in the city of Munich) and information on behavioural problems. Additionally, we excluded children who were living for less than 1 year at their current place of residence. A total of 2949 children from Munich were recruited at birth for GINIplus from which 1730 (58.7%) participated at the follow-up 10 years later. In LISAplus, 1467 children from Munich were originally recruited and 940 (64.1%) were followed up to 10 years. After exclusion of children not meeting the above-mentioned criteria, the study population for the current study consists of 872 children (583 from GINIplus and 289 from LISAplus). For 287 of the 289 LISAplus children additional information on sleeping problems was available.

2.2. Noise exposure measurement

Road traffic noise data used within the current study is based on the Munich noise map, which was created for the year 2007. Birk et al. (2011) provides some details on the road traffic noise modelling procedure. CadnaA software ("Computer Aided Noise Abatement", see DataKustik website: 〈http://www.datakustik.com/index.php?id=52&L=1〉) was used for the calculations based on a 3-dimensional terrain model to account for multiple reflections and shielding from objects, including houses and other noise barriers. Modifying effects of traffic noise protection measures such as noise shield walls and also of buildings were considered in the noise model. Two noise indicators defined according to the European Environmental Noise Directive (Directive 2002/49/EC, 2002) and its implementation into German law-the 34th Federal Immission Control Ordinance (34. BImSchV, 2006)-were available for all children studied. First, the night noise indicator L_{night} is defined as the A-weighted long-term average sound level determined over all night periods (8 h: 10 p.m.–6 a.m.) of the year. This indicator can be used to measure sleep disturbance by noise. Second, the day–evening–night noise indicator L_{den} can be used to assess overall noise annoyance and accounts for increased levels of disturbance by noise during the evening and night times. It is defined by

$$L_{\mathrm{den}} = 10\lg\frac{1}{24}\left(12\times 10^{\frac{L_{\mathrm{day}}}{10}} + 4\times 10^{\frac{L_{\mathrm{evening}}+5}{10}} + 8\times 10^{\frac{L_{\mathrm{night}}+10}{10}}\right)$$

where L_{night} is defined as above and L_{day} and L_{evening} are the A-weighted long-term average sound levels, determined over all day (12 h: 6 a.m.–6 p.m.) and evening (4 h: 6 p.m.–10 p.m.) periods of the year, respectively (Directive 2002/49/EC, 2002; WHO, 2011). The German definition of noise indicators (34. BImSchV, 2006) differs slightly from the proposed definitions in the Directive 2002/49/EC, 2002 in terms of a 1 h earlier beginning of the day, evening and night period. A-weighted sound pressure levels (expressed as dB(A)) are applied as they account for the fact that the same sound pressure level is perceived differently at different frequencies by the human ear (Ouis, 2001). Noise exposure of the children at their home address was defined by maximum and minimum levels of L_{den} and L_{night} calculated over all noise levels at façade grid points for each building representing the noise at the most (max(L_{den}) and max(L_{night}), respectively) and least exposed façade (min(L_{den}) and min(L_{night}), respectively).

2.3. Health outcomes

Behavioural problems at the age of 10 years were assessed by the German parent-reported version of the SDQ (Goodman, 1997; Goodman et al., 1998; Woerner et al., 2002; Woerner et al., 2004). The SDQ is an internationally disseminated and validated behavioural screening questionnaire for 3-to 16-year-olds. The five dimensions (emotional symptoms, conduct problems, hyperactivity/inattention, peer relationship problems and prosocial behaviour) are covered by five SDQ items each, resulting in 25 items total. A three-point scale with response options 'not true' (0), 'somewhat true' (1) and 'certainly true' (2) was used for scoring each item (e.g. 'Many worries, often seems worried.'). Positively worded items were reverse-scored. Ratings of the subscale items are summed to give subscale scores. According to the standard scoring instructions on 〈http://www.sdqinfo.org〉, subscale scores were prorated in case at most two out of five scale items have been omitted. The total difficulties score is obtained by summing all subscale scores except for the prosocial behaviour score. The total difficulties score and the subscale scores were categorised into normal, borderline or abnormal according to cut-off points recommended for German samples (Woerner et al., 2004). The analyses in the present study are restricted to the four problem scales of the SDQ (excluding prosocial behaviour) and the total difficulties score. Current sleeping problems at the age of 10 years were assessed for children of the LISAplus cohort. Three dichotomous variables measure the presence of any sleeping problems and, in more detail, difficulties to fall asleep or difficulties sleeping through the night.

2.4. Definition of covariates

Basic characteristics of the children in the study such as sex, age and study (GINIplus-interventional group or observational group, LISAplus) were extracted from questionnaires. Additional covariates potentially related to confounding were chosen based on previous similar studies (e.g. Lercher et al., 2002; Crombie et al. 2011). Parental educational level and single parent status were included to reflect the socioeconomic status of the family of the study child.