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Urban ambient outdoor and indoor noise exposure at home: A population-based study on schoolchildren

Sophie Pujol [a,b], Marc Berthillier [c], Jérôme Defrance [d], Joseph Lardiès [c], Rémy Petit [e], Hélène Houot [f], Jean-Pierre Levain [g], Cyril Masselot [f], Frédéric Mauny [a,b,]*

[a] Laboratoire Chrono-environnement, UMR 6249 CNRS/Université de Franche-Comté, 25030 Besançon Cedex, France
[b] Centre hospitalier régional universitaire de Besançon, 25030 Besançon Cedex, France
[c] UMR CNRS/Université de Franche-Comté, Institut FEMTO-ST 6174, 24 chemin de l'épitaphe, 25000 Besançon, France
[d] Centre scientifique et technique du bâtiment, Département Acoustique et Eclairage, 24 rue Joseph Fourier, 38400 Saint-Martin-d'Hères, France
[e] Inspection académique du Doubs, 26 avenue de l'Observatoire, 25030 Besançon Cedex, France
[f] UMR CNRS/Université de Franche-Comté «ThéMA» 6049, UFR Lettres SHS, 32 rue Mégevand, 25030 Besançon Cedex, France
[g] Laboratoire de Psychologie, EA 3188, IUFM de l'Université de Franche-Comté, Fort Griffon 25042 Besançon Cedex, France

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ABSTRACT

To investigate residential exposure to environmental noise among children in an urban area, a noise measurement campaign was performed at the residences of 44 schoolchildren. Outdoor and indoor noise levels were simultaneously recorded during one week inside and outside each child's bedroom and in the other room where each child spent most of his or her time, called "the main room". Associations between equivalent noise levels and familial or environmental characteristics were explored.

The recorded equivalent continuous sound levels (L_{Aeq}) were prone to large variability between dwellings regardless of the measurement location and time of day. Factors linked to outdoor noise level differed from those associated with indoor noise level. Indoor noise levels were associated with the number of children present and noise sources present in the dwelling, whereas outdoor L_{Aeq} depended significantly on the socio-economic status (SES) of the household. An association was found between the type of view from the window and outdoor L_{Aeq}, but no significant association was observed between view from the window and indoor L_{Aeq}. These results support a complex link between noise exposure and the characteristics of the dwelling and of the family, and highlight the contribution of the indoor noise sources to the ambient noise level.

Considering the observed acoustic levels and their variability, the sensitivity of children to noise, and the length of time they spend at home, research efforts are needed to better quantify noise exposure at home if the actual burden of noise on child health is to be identified.

1. Introduction

Noise is a ubiquitous environmental pollutant with well-documented adverse effects on hearing. Exposure to noise can also cause non-auditory effects, including hypertension, cardiovascular disease, annoyance, or sleep disturbance, and can impair some cognitive processes [1–5]. In urban areas, the most widespread noise sources are transportation and industry.

Approximately 26% of the population of the European Union is subject to environmental noise levels greater than 55 dB L_{den}, which is considered potentially harmful to health [6]. Children are particularly vulnerable to the effects of noise because of its potential to interfere with learning at a critical development stage. Furthermore, children's abilities to anticipate, understand, and cope with stressors are less developed than those of adults [4,7].

Several indicators can be used to describe noise exposure. The most commonly used is the equivalent continuous sound level ($L_{Aeq,T}$, in dB), which represents the predicted or measured sound energy average over a stated time period T. Most epidemiological studies that have focused on the effect of noise on health have been based on theoretical models that used traffic counts and patterns of sound propagation in the environment to assess outdoor long-term sound levels [8–11]. Some studies considered noise measurement in front of residences [1,12] to accurately reflect the outdoor noise level. These approaches deal with outdoor conditions, but the

* Corresponding author at: Laboratoire Chrono-environnement, UMR 6249 CNRS/UFC, CHRU de Besançon, Centre de Méthodologie Clinique, 2 place Saint Jacques, 25030 Besancon Cedex, France. Tel.: +33 (0)3 81 21 90 46; fax: +33 (0)3 81 21 87 35.
E-mail address: frederic.mauny@univ-fcomte.fr (F. Mauny).

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relationship of ambient noise with the indoor environment, where people spend more than 80% of their time, is complex and unclear.

Indoor noise levels appears difficult to quantify at home, especially when children are considered, and are likely related to the presence and number of people living in the dwelling, as well as their activities. To account for spatial and temporal fluctuations, noise levels should be measured in several locations over an extended time period. Thus, the living habits and conditions of a family at home may be poorly represented by the usual acoustic measurements. To our knowledge, few studies have focused on measuring indoor home noise exposure [13–16], and the actual level of noise exposure remains unknown.

This survey was conducted among families living in urban areas. The aim of this study was to quantify children's exposure to indoor and outdoor noise levels and to investigate the factors influencing these levels.

2. Methods

2.1. Population

This study was conducted among pupils attending one of the 35 public primary schools in key stage 2, year 4 in the city of Besançon from 2006–2007 (aged 8 and 9 years). Among these 900 children, a calling list was randomly drawn up. The parents of the sampled children were invited by phone to participate in the study and were screened for the following inclusion criteria: residence in the city of Besançon at the same location for at least 1 year; child's bedroom located on the first floor or higher or at ground floor with a private garden or courtyard; and the size of the bedroom's window being suitable for fastening measurement equipment. Dwellings were equipped in order of acceptance of the families, according to the availability of inhabitants and measurement equipment, and avoiding long holiday periods. Despite the uncertainty on indoor noise level and its variability, we calculated a minimum number of dwellings to be included in the study to insure a statistical power of 80%. Calculation for a two-group comparison (with the following parameters: difference = 5 dB; standard deviation = 5 dB; mean = 50 dB) as well as for a correlation test ($r \geqslant 0.33$) provided a minimum sample size of 35 dwellings. To take into account the unknown family acceptance rate, noise equipment availability, and the school calendar, the calling list was set to 10% of the 900 schoolchildren.

2.2. Social survey/Potential confounding factors

At the first visit, the following information was obtained: type of view from the main room and bedroom windows, type of window (single glazed, double glazed, extra glazed, double window), and presence of indoor noise sources (radio, television, musical instrument, computer, or others). Standardised questionnaires were distributed to the parents and collected at the end of the measurement period. The type of neighbourhood (whether the majority of households were in collective buildings, detached houses, or whether the neighbourhood was mixed) and dwelling (detached house, semi-detached house, or collective building) were recorded. Measured household characteristics included socio-economic characteristics (single parenthood and parental occupation, employment status, and educational level), family size, number of residents, duration of residency, child's age, sex, and birth order, number of rooms, and floor level of the dwelling. Families were asked to report the presence of adults and children in the dwelling and noisy events occurring indoors (use of television, radio, musical instruments, or household appliances) and outdoors each day by periods of 30 min.

2.3. Noise measurement

The study was performed at the subjects' homes from December 2006 to July 2007 using three measuring chains in parallel. Each chain was composed of a sound level meter (Blue Solo® from 01 dB-Metravib) and a front-end acquisition equipment (Harmonie® or Symphonie®, 01 dB-Metravib) that was connected to a computer. The acoustic equipment was class 1 and complied with technical standards NF S31-010 [17]. An omnidirectional loudspeaker (JORAN from ATOHM) was used to emit pink noise generated by the digital analyser. Noise level was measured at a height of 1.15 m (child ear height) using the following two kinds of microphone support: "conventional" tripods (Manfrotto®) and "adapted" support, where lamps developed for the study were equipped with a specific fastening and a lampshade to hide the microphone without disturbing the noise signal. The measurement chains were calibrated at the beginning and end of the measurement sessions (Cal 21, 01 dB-Metravib).

An acoustic characterisation was performed in the child's bedroom and the room where the child spent most of his or her time outside the bedroom, termed the "main room". Background noise levels were measured during 20 s in accordance with NF EN ISO 140-4 [18] in the following conditions: windows closed, usual layout and door positions maintained. To choose the location of the inner microphone for the 8 days of measurement, sound levels were first evaluated at four different locations in the two rooms (Fig. 1). Two "conventional" locations were defined according to usual acoustic characterisations (room centre and 1/3 of the length of the diagonal on the opposite side of the room from the noise source). In two "adapted" locations, microphones were placed based on a trade-off between conventional locations and family constraints. The "trade-off" measurement location was maintained for the eight measurement days (avoiding locations close to walls, windows, doors) and measurement locations were considered to have "deteriorated" if the microphone was moved by the family. The noise level differences between the four locations were less than 3 dB for all the study dwellings. The reverberation time (RT) was also measured in accordance with NF EN ISO 140-4 using an interrupted stationary signal in octave band (63 Hz–4 kHz). Weighted standardised sound level difference between the child's bedroom and the main room ($D_{nT,A}$) was measured in compliance with NF EN ISO 140-4 and NF EN ISO 717-1 [19] when the doors between the bedroom and the main room were arranged in the following three ways: the doors were all closed, the doors were all opened, and the doors were opened as usual during the night. The omnidirectional loudspeaker emitting a continuous pink noise of 100 dB was located in the main room. L_{Aeq} and noise spectra based on one-third octave band sound levels were measured simultaneously for 20 s in the child's room and the main room. The reference RT was 0.5 s.

Acoustic equipment was installed for an eight-day period. The L_{Aeq} and noise spectra (12.5–20 kHz, one-third octave band) were

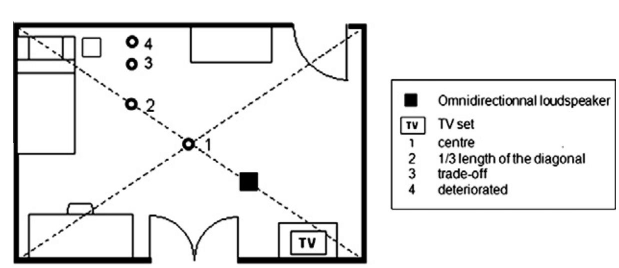

Fig. 1. Microphone placement during the acoustic characterisation and the eight-day measurement period in the bedroom.