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Short-term associations between traffic-related noise, particle number and traffic flow in three European cities

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HIGHLIGHTS

- 20-min measurements of air pollution, noise and road traffic were taken at 141 sites.
- Traffic noise levels and traffic counts were far more constant over time than ultrafine particles number concentrations.
- Simultaneous measurements of traffic count and noise were moderately to well correlated.
- Simultaneous measurements of ultrafine particles and noise were poorly correlated.
- This should allow future studies to disentangle the short-term effects of ultrafine particles and noise.

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ABSTRACT

Outdoor noise and particulate matter concentration share common sources, including road traffic in urban areas, raising the potential for mutual confounding in epidemiological studies of their health effects. While some studies evaluated their long-term correlation, little is known about their short-term correlation. Our aim was to study the correlation of short-term noise, ultrafine (<0.1 μm) particulate matter number concentration (UFP), and traffic flow in urban areas. A secondary aim was to document the temporal variability of these short-term measurements. We simultaneously measured traffic noise levels, UFP concentrations as well as motor vehicles' flows for 20 min in 141 locations, on one to three occasions, in three middle size European cities (Basel, Girona, Grenoble). The reproducibility of the short-term noise measurements and traffic counts over time was high, as reported by the intraclass correlation coefficient (ICC), which quantified the agreement between repeated measurements (ICC = 0.86–0.97, according to city, for noise and ICC = 0.93–0.94 for traffic counts); this was not the case for UFP number concentrations (ICC = −0.11 to 0.14). The Pearson correlations of simultaneous 20-min measurements of UFP number concentrations and noise levels were in the 0.43–0.55 range, depending on the city; correlations between noise levels and vehicle counts varied from 0.54 to 0.72; and correlations between UFP concentrations and vehicle counts were lower (r = 0.15–0.37 depending on the city). Measurements during as little time as 20 min of outdoor noise and traffic, but not of UFP, were strongly reproducible

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over durations of a couple of days or months in middle-size European cities. In these areas, on the short-term, noise levels and UFP concentrations exhibited relatively moderate correlations, which may allow adjustment for mutual confounding in epidemiological studies, thus allowing to disentangle their possible short-term health effects.

1. Introduction

A large body of evidence indicates that atmospheric pollutants impact human health, in particular cardiovascular, respiratory functions, and possibly reproductive and neurological diseases (World Health Organization, 2013). For some of these diseases, such as those related to the cardiovascular system, the specific role of traffic-related air pollution has been emphasized (Peters et al., 2004). Road traffic generates atmospheric pollutants such as ultrafine particles (typically in the 10–500 nm diameter range) and a large number of gaseous pollutants. In addition, traffic is a source of noise. Noise may also impact health, particularly cardiovascular health (Tétreault et al., 2013; Kempen and Babisch, 2012, Babisch et al. Noise and Health Editorial, 2012; Basner et al. The Lancet, 2013) and possibly birth outcomes (Gehring et al., in press).

In epidemiological terms, noise thus constitutes a potential confounder in the study of the association between atmospheric pollutants and health. Reciprocally, traffic-related air pollution constitutes a potential confounder in the association between noise and specific health factors. Clear identification of the respective role of these two stressors has not been accomplished (Foraster, 2013, Tétreault et al., 2013).

The correlation between traffic-related air pollution and noise levels has been previously considered (Allen et al., 2009; Can et al., 2011; Davies et al., 2009; Foraster et al., 2011; Sorensen et al., 2011). However, to our knowledge most research has focused on long-term averages, in an attempt to understand their mutual confounding effect in chronic diseases (Tétreault et al., 2013). In Girona, Spain, Foraster et al. reported a correlation of 0.62 between yearly averages of nitrogen dioxide (NO_2) levels based on measurements and modelled yearly averages of traffic noise levels. To our knowledge, the spatial association between noise and particulate matter levels (an atmospheric pollutant for which clear associations with cardiovascular health have been reported (Brook et al., 2010)) has so far been studied only once (Allen et al., 2009). The short-term correlations of noise and particulate matter have received even less consideration. This study is of importance because air pollution and noise may also have short-term effects (Huang et al., 2013). To understand these associations, concurrent measurements of noise and air pollution as well as traffic density are needed. Comparisons of the associations between road traffic density and either noise or air pollution levels are also of interest, as road traffic is a major determinant of air pollution and noise in urban settings.

Thus, our aims were to describe the correlations between 20-min simultaneous measurements of noise, ultrafine particle number concentrations, and traffic flows, as well as the temporal variability of these measurements. We also investigated the potential determinants of ultrafine particle number concentrations and noise levels in each city.

2. Materials and methods

2.1. Study areas

This work was part of the Tri-Tabs project (Tri-national project on traffic, air, noise and health), which involves the participation of three European centers: Basel (Switzerland; 193,000 inhabitants in the city in 2011 and 850,000 in the urban area), Girona (Spain; 96,700 and 336,000 inhabitants, respectively) and Grenoble (France; 156,000 and 670,000 inhabitants, respectively). For each city, at least 40 sites were carefully selected to capture the contrast of the road traffic noise and ultrafine particle number (UFP) concentrations, e.g. sites that are directly affected by road traffic flow; sites representing an urban background and a few sites in parks and gardens to represent regional background. Moreover, additional sites were chosen in the city-centre as well, with different predispositions to air pollution levels, traffic noise, and road traffic flows. We selected 60 sites in Basel, 40 sites in Girona and 41 sites in Grenoble. For each city, the number of measurements sites was similar to what is commonly used in the land-use regression (LUR) literature to characterize fine particulate matter or nitrogen dioxide levels even in larger cities (Eeftens et al., 2012). The choice of sites' locations was based on a deterministic approach, in order to cover the range of traffic, noise and air pollution levels in the urban area and have a homogeneous urban cover and avoid the proximity to sources of disturbance regarding the three exposure markers. To maximize comparability across measurements at the several sites, all measurements were done in non-rush hours. Up to 8 sites were measured each day. For a given site, each repeated measurement was done in a second campaign (Girona, Grenoble) or a third one (Basel). When weather conditions or construction work did not allow the measurement, this one was relocated to another day.

All locations were geocoded. Depending on the city, we conducted two (Grenoble, Girona) or three (Basel) repeated measurements in different campaigns, either at all sites (Basel) or at a subset of sites. For the second measurement campaign, 25 sites were selected in Girona and 26 in Grenoble. The measurements in Basel were taken at three different seasons, while measurements in Girona and Grenoble were repeated within close time intervals (see Table 2 for the exact dates of the measurements campaign).

2.2. Noise, particulate matter and traffic measurements

The three variables of interest were UFP concentrations, traffic-related noise and road traffic flow. They were measured simultaneously at a given site, for a total duration of 20 min during non-rush hours (defined separately for the three cities) and during weekdays only. Ultrafine air pollution levels were assessed by measuring total UFP concentrations with a minidisc portable particle counter (FHNW, Windisch, Switzerland) in Basel and a Ptrak device (TSI, Shoreview, MN, USA) in Girona and Grenoble, which were deployed on a tripod at 1.5 m height.

Equivalent continuous levels of noise (LAeq averages, in dB(A)) were measured. The sound level meter used in Girona and Grenoble