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Field study on the impact of nocturnal road traffic noise on sleep: The importance of in- and outdoor noise assessment, the bedroom location and nighttime noise disturbances

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HIGHLIGHTS

- We studied the impact of nocturnal road traffic noise on sleep and well-being
- We used in- and outdoor noise assessment, sleep logs, actigraphy and questionnaires
- Noise exposed subjects reported an overall discomfort due to traffic noise.
- Reported noise disturbances and sleep were related; SOL and SQ being affected
- Clear and characteristic noise patterns for a noise and quiet region were found

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ABSTRACT

The aim of this field study is to gain more insight into the way nocturnal road traffic noise impacts the sleep of inhabitants living in noisy regions, by taking into account several modifying variables. Participants were tested during five consecutive nights in their homes and comparisons between effective indoor and outdoor noise levels (L_{Aeq}, L_{Amax}, number of noise events), sleep (actigraphy and sleep logs) and aspects of well-being (questionnaires) were made. Also, we investigated into what extent nocturnal noise exposure – objectively measured as well as perceived – directly relates to sleep outcomes and how the bedroom location influenced our measurements.

We found that subjects living and sleeping in noisy regions correctly perceive their environment in terms of noise exposure and reported an overall discomfort due to traffic noise. In the evaluation of the objective noise levels, the inside noise levels did not follow the outside noise levels, though the different noise patterns could be described as characteristic for a noise and quiet environment. The impact on sleep, however, was only modest and we did not find any influence of noise intrusion on mood or pre-sleep arousal levels. Concerning the subjectively reported noise disturbances during the night, a clear relationship between noise and sleep outcomes could be established; with sleep onset latencies and judged sleep quality being particularly affected.

The importance of inside and outside noise assessment as well as the use of multiple noise indicators in a home environment is further described. Additional emphasis is put on the determination of quiet control regions and the bedroom location, as this can alter noise levels and sleep outcomes. Also, including subjective noise evaluations during the night might not only provide crucial information on how participants experience the noise, but also allows for a more qualitative interpretation of the actual noise situation.

1. Introduction

Among the various noise sources, transportation noise during the night can be categorized as the most disturbing for sleep and recuperation (Muzet, 2007; World Health Organization—WHO, 2011). The effects of nocturnal road traffic noise on sleep have been extensively studied during the last decades. In laboratory studies, specific attention was paid on the establishment of dose–effect relationships and more recently, on the different sleep disturbing effects following single and combined traffic noise exposure (Basner et al., 2011; Eberhardt et al., 1987; Öhrström and Rylander, 1990). Results of large-scale field studies investigating the effects of road traffic noise on sleep using questionnaires and sleep logs tend to point in the same direction; that is, a worsening of sleep and a decreased general well-being in regions with

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increased nocturnal traffic noise (Belojević et al., 1997; Jakovljević et al., 2006; Öhrström, 1991, 2004a; Öhrström and Skånberg, 2004; Stošić et al., 2009; Van Renterghem and Botteldooren, 2012). Some studies investigated sleep disturbances together with daytime functioning and observed an overall mood deterioration – mostly in the morning – in noise exposed persons as well as psychological and somatic disturbances such as fatigue, nervousness or headaches (Belojević et al., 1997; Öhrström, 1989, 2004b).

In large-scale field studies, data of representative population samples can be collected, in this way enhancing the validity of the outcome measures. However, as individual inside noise levels are very difficult to collect in such large samples, noise evaluation relies on outside measurements and calculations. In their review of non-auditory effects of noise on health, Stansfeld and Matheson (2003) pointed out that a low association between outdoor noise levels and sleep disturbances exists. The lack of precise individual inside noise levels in home studies is a well-known shortcoming and despite this, only scarce information on such measurements and its relationship with sleep is available in the literature (Griefahn and Gros, 1986; Passchier-Vermeer et al., 2007; Pirrera et al., 2011; Tulen et al., 1986; Vallet et al., 1983). Other studies did not find any relation between objective noise levels and sleep outcomes (Griefahn et al., 2000; Nivison and Endresen, 1993).

Furthermore, in exploring a relationship between noise and sleep, it has been amply demonstrated that the degree of noise exposure is not the only factor impacting sleep. Numerous acoustical and non-acoustical factors, such as noise sensitivity or bedroom orientation, do play an important role in the determination of noise induced sleep disturbances in the home situation (Bluhm et al., 2004; de Kluizenaar et al., 2013; Marks and Griefahn, 2007; Paunović et al., 2009; Urban and Máca, 2013; Van Renterghem and Botteldooren, 2012; Welch et al., 2013). Also, information on how the noise is perceived during the night can contribute to a better understanding of the noise–sleep relationship (Murphy and King, 2014). The subjective experience of the noise exposure or disturbance is usually translated through the concept of annoyance. Noise annoyance reactions, whether occurring during daytime or nighttime, are considered to be stress reactions, as they include different affective, psychological and physiological components (Dratva et al., 2010; Guski et al., 1999; Ouis, 2002). A number of studies found a close relationship between the degree of nighttime noise annoyance caused by road traffic and poor sleep (Fyhri and Aasvang, 2010; Jakovljević et al., 2006; Öhrström, 1991, 1993; Van Renterghem and Botteldooren, 2012).

All these findings stress the importance of exploring different pathways in the assessment of road traffic noise and its influence on sleep in a home environment. The aim of this study is to gain more insight into the way nocturnal road traffic noise impacts the sleep of inhabitants living in noisy regions. To this end, we compared the effective indoor and outdoor noise levels during the night, sleep and mood between inhabitants of noisy and quiet regions in the Brussels-Capital Region. How does the objectively measured and perceived noise, as well as the other variables, differ in both groups, and how concordant are these different measurements in each group? Also, we investigated into what extent nocturnal noise exposure – objectively measured as well as perceived – directly relates to sleep outcomes and how the location of the bedroom influenced our measurements.

2. Method

2.1. Procedure and material

2.1.1. Selection of the locations and study population

Subjects living in noisy regions, or the so-called “black spots”, were recruited by mail. These “black spots” are defined by the Brussels Institute for Management of the Environment (BIME; www.leefmilieubrussel.be) as “Residential or building areas with either a concentration of various types of noise pollution, or a high number of complaints concerning noise pollution.” An additional screening of these areas was performed in order to avoid a maximum of confounding variables, such as noises from pubs, restaurants and others. Approximately 1050 letters were sent out, and from the 40 responses we received, 24 subjects fulfilled all inclusion & exclusion criteria and agreed to participate. The same procedure was applied for the recruitment of subjects living in quiet regions of Brussels (www.leefmilieubrussel.be), where 1400 letters were distributed. Here as well, a very low response rate was observed, which was expected, considering the high demands towards the participants. Out of the 21 reactions we received, 11 persons fulfilled all criteria and agreed to participate. Additionally, other recruitment channels, for example the newsletter of the Brussels' University, were used. This led to the enrollment of another 13 persons. In total, the quiet group consisted of 24 subjects. One participant in the noise group and two participants in the quiet group were removed from the study sample; both because of noise and sleep issues.

Inclusion and exclusion criteria were a regular sleep–wake schedule, a good general health, no children under 10 years of age, no shift or night work, no pregnancy, an alcohol usage not exceeding 15 consumptions a week, no medication that alters sleep (antidepressants, hypnotics, tranquillizers), having a professional activity in the Brussels-Capital Region and living in a noisy or quiet region for at least one year.

For the noise group, 23 subjects fulfilled all criteria and were included in this study (average age of 42 years; ages between 22 and 62; 15 females, 8 males). The quiet group consisted of 22 subjects, with an average age of 42 years (ages between 23 and 64; 15 females, 7 males). The averaged length of residence for the noise and the quiet group did not statistically differ [respectively 5.6 and 9.5 years; $U = 150$; non-significant (ns)].

69% of the studied locations in the noise group were apartments (1st–7th floor), 26% were enclosed houses and 4% were semi-detached houses. 82% of the bedrooms had double-glazed windows and faced the roadside in 39% of the cases. For the quiet group, 32% of the studied locations were apartments (1st–7th floor), 45% were enclosed houses, 13% were semi-detached houses and 9% detached houses. 85% of the bedrooms had double-glazed windows and faced the roadside in 54% of the cases.

2.1.2. Assessment of nocturnal road traffic noise

Traffic noise was recorded inside and outside each bedroom place during seven consecutive nights using an Integrator Class 1 (inside) and Class 2 (outside) Sound Level Meter (SLM; Metravib®). The measurement range was 20–137 dB(A) for Class 1 and 30–137 dB(A) for Class 2 SLM. The outside sound level meter was set up at the outside façade of each bedroom. The microphone was attached at a distance of $\pm$0.5 m from the window, using balconies or other possibilities and taking into account safety measures for possible vandalism and robbery. Indoor noise was recorded inside each bedroom, near the head of the bed where possible, according to the accessibility to a power supply.

An averaged noise level value per 30-second epoch was recorded from 10 P.M. to 08 A.M. during seven consecutive nights. Noise data was analyzed with the software program dBTrait (version 4.805).

For the subjective evaluation of traffic noise disturbances during the night, subjects completed a visual analog scale (VAS) every morning. They were asked to rate, using a 100 mm line from 0 to 10, into what extent they were disturbed by noise during the night. Additionally, they completed open questions on the sources and the frequency of occurrence of the noises.

2.1.3. Assessment of sleep

Actigraphic recordings, type Sensewear Armband Pro2 from Bodymedia Inc. Sensewear®, were made during seven consecutive nights. Analyses were performed with Innerview Professional 5.0. software and derived sleep variables were: Time in Bed (TIB: lying down period), Sleep Onset Latency (SOL: calculated from the start of the TIB period to the first consecutive three minutes of sleep scoring), Wake