Nocturnal road traffic noise and sleep: location of the bedroom as a mediating factor in the subjective evaluation of noise and its impact on sleep

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INTRODUCTION

The impact of noise intrusion on sleep and daytime functioning is well illustrated in the literature, where results of both laboratory and field studies are reported (Griefahn 2002; Muzet 2007). One challenge in the elaboration of field studies on the impact of road traffic noise on sleep concerns the indoor noise assessment. Only a few field studies assessed indoor noise levels on a daily basis (Eberhardt & Akselsson 1987; Vallet et al. 1983). Other large-scaled field studies – though showing consistent results for sleep disturbances - were unable to collect individual noise levels due to large population samples and therefore needed to rely on outside noise measurements (Öhrström 1991 & 1989; Belojević & Jakovljević 1997; Stošić et al. 2009). Another element that complicates field studies on noise and sleep is the fact that in addition to noise exposure, a large number of mediating factors play an important role in the contribution of noise to sleep disturbances (Ouis 2001; Muzet 2007). Of the many mediating factors investigated, little research was performed on the effects of the bedroom location on the relation between inside and outside noise levels, on noise perception and on sleep disturbances in highly noise exposed regions. One study performed by Öhrström (1993) reported a decrease in sleep quality, longer sleep onset latencies and lower values in terms of psycho-social wellbeing in subjects sleeping at the street side compared to subjects sleeping at the backside of their houses, both located in high density of road traffic regions. In most studies, this issue is addressed by putting the bedroom orientation as an inclusion criterion (e.g. all street side) or by measuring noise levels outside at the bedroom façade (Öhrström 1991; Öhrström & Skånberg 2004; Stošić et al. 2009). Other studies derived the bedroom location from questionnaires and corrected the noise levels outside according to it (Öhrström 1989, 2004; Belojević & Jakovljević 1997).

This sub-study is a part of a longitudinal study investigating the relationship between nocturnal road traffic noise, sleep quality and general well-being of inhabitants of the Brussels' Capital Region. In this study, results of the assessment of differences in outside as well as inside noise levels according to the bedroom location are presented. We also investigated in what extent the location of the bedroom influences the traffic noise perceived during the night and its impact on sleep.

METHOD

Study population

Subjects were recruited by mailing in the so-called "black spot" regions in Brussels. These regions were already defined and mapped by the Brussels Institute for Management of the Environment (BIME). "Black spots" are defined as 'Residential or building areas with either a concentration of various types of noise pollution or a high number of complaints concerning noise pollution' (www.leefmilieubrussel.be). An ad-

ditional screening of those regions was performed so a maximum of confounding variables such as noises from pubs, restaurants and others could be avoided.

21 subjects were included in this study and were divided in two groups according to their bedroom orientation. In the first group, eight subjects (6 males, 2 females, average age 45 years) had their bedrooms located at the street side. 50 % lived in apartments (1^{st} to 3^{rd} floor), 37 % in enclosed houses and 13 % in semi-detached houses. 88 % of the bedroom places had double-glazed windows. The second group consisted of thirteen subjects (9 females, 4 males, average age 40 years) sleeping at the backside of their apartments (85 %, ground floor to 8^{th} floor) or enclosed houses (15 %). 85 % of the bedroom places had double-glazed windows.

Inclusion and exclusion criteria were a good general health, a regular sleep-wake schedule, no children or children above 10 years of age, no shift or night workers, no pregnancy, no alcohol consumption of more than 15 units a week and no medication that alters sleep such as hypnotics, antidepressants or tranquilizers. Also, all subjects lived in noisy regions for at least one year.

Nocturnal road traffic noise

Traffic noise was recorded inside and at the outside façade of each bedroom place during five consecutive nights. We used an Integrator Class 1 (inside) and Class 2 (outside) Sound Level Meter (SLM; Metravib®) with a measurement range of respectively 20-137 dBA and 30-137 dBA. For the outside SLM, we attached the microphone at the outside façade of each bedroom place with a distance of ± 0.5 m from the window, using balconies or other possibilities and taking into account safety measures for vandalism or robbery. The indoor SLM was installed in the bedroom, where possible near the head of the bed and according to the accessibility for power supply. A mean noise level value per 30-second was recorded from 22 PM to 08 AM. Noise data were analysed with the software program dBTrait (version 4.805).

Sleep logs and subjective evaluation of nocturnal road traffic noise

Sleep logs were completed every morning during five days. Questions included time to go to bed, time of lights out, an estimation of sleep onset latency (SOL), estimation of the number and reason for awakening during the night, time of wake up and subjective evaluation of sleep quality (SQ; 1 = very bad sleep; 2 = rather poor sleep; 3 = slept reasonably well; 4 = slept very well). Sleep parameters analyzed in the framework of the current paper were SOL and SQ.

For the evaluation of the experienced nocturnal noise, a visual analog scale (VAS) was used. Subjects were asked every morning to rate their degree of disturbance due to noise on a 100 mm line ranging from 0 to 10. Additionally, questions on the source and the frequency of occurrence of the noise sources were included.

This study was approved by the Ethics Committee of the Free University of Brussels. Data recording took place from 9/2006 till 5/2007. Holiday and weekend periods were excluded due to the diminished road traffic volume. Weekdays are defined as Monday referring to the night from Sunday to Monday and accordingly for the rest of the week.

Analysis and statistical design

For the noise analyses, we calculated L_{Aeq}, L_{Amax} and number of noise events of the inside and outside noise measurements from 23 PM to 07 AM. The noise events were categorized in accordance with the sleep disturbances and health effects observed in the population as described by the WHO (2009).

Range 1: noise events from 30 dBA to 40 dBA: Increase in primary sleep disturbances.

Range 2: noise events from 40 dBA to 55 dBA: Sharp increase in adverse health effects in a large part of the exposed population.

Range 3: noise events above 55 dBA: Adverse health effects occur frequently.

As not all of the data sets appeared normally distributed and both groups consisted of small study samples, non-parametric Mann-Whitney U Tests were used to compare L_{Aeq}, L_{Amax} and number of noise events, the sleep variables SOL and SQ and the mean scores of the VAS. Chi-square tests were used to compare detailed results of the VAS.

RESULTS

Noise measurements

Table 1 represents an overview of the mean noise levels in L_{Aeq}, L_{Amax} and number of noise events measured inside and outside the bedroom place located at the street or at the backside of the dwelling. For the outside noise measurements, all noise indicators - with the exception of the lower range of noise events - were statistically significantly different with higher noise levels measured at the street side compared to the noise levels at the back side. This was however not the case for the inside noise levels, where no differences between the noise levels at the street and the backside could be found. For the number of noise events inside in range 3 (above 55 dBA), we found them in more than 50 % of the nights to be absent so no further analysis was performed.

Table 1: Overview of the mean noise levels per noise indicator inside and outside the bedroom at the street and backside and their significance level

Noise indicator	Street side	Backside	p level*
$L_{Aeq, outside, 23-07}$	66.1 dBA *(65.5 – 66.8 dBA)*	50.5 dBA *(48.7 – 51.7 dBA)*	<0.001*
$L_{Amax outside, 23-07}$	84.2 dBA *(80.5 – 86 dBA)*	69.4 dBA *(65.6 – 70.5 dBA)*	<0.001*
Noise events, outside R1: 30-40 dBA**	0.9 % *(0.2 - 1.6 %)*	12.5 % *(5.7 - 15.4 %)*	0.10
Noise events, outside R2: 40-55 dBA**	24.7 % *(19.2 - 28.7 %)*	81.6 % *(76.7 - 90.8 %)*	<0.0001*
Noise events, outside R3: above 55 dBA**	74.8 % *(69.7 - 80.6 %)*	5.3 % *(2.9 - 9.2 %)*	<0.0001*

Noise indicator	Street side	Backside	p level*
$L_{Aeq, inside, 2307}$	38.4 dBA *(36 – 40.7 dBA)*	40.1 dBA *(36.9 – 42.3 dBA)*	0.59
$L_{Amax, inside, 23-07}$	62.6 dBA *(57 – 66.8 dBA)*	59.2 dBA *(55.2 – 61 dBA)*	0.59
Noise events, inside R1: 30-40 dBA**	39.6 % *(37.5 – 40.9 %)*	31.9 % *(23.8 - 38.1 %)*	0.50
Noise events, inside R2: 40-55 dBA**	5 % *(4.1 - 5.8 %)*	6.2 % *(5.5 - 7.1 %)*	0.46

* p-level statistically significant at .05

** Mean percentage of number of epochs in which noise events occur relative to the total number of epochs over a complete night.

Subjective evaluation of noise disturbances

The average results of the subjective evaluation of noise disturbances and the report of specific noise sources during the night are summarized in Table 2. No significant differences were found in the overall evaluation of noise disturbances during the night. For the specific noise sources, significantly more disturbance due to road traffic noise was reported in subjects having their bedroom located at the street side. Also, significantly more quiescence was reported by subjects sleeping at the backside of their dwelling.

Table 2: Weekly average score of level of overall noise disturbance and percentage of participants subjectively reporting specific noise disturbances during the night as assessed with the VAS

	Street side	Backside	p-level*
Mean score/10	1.5	1.6	0.45
Noise sources			
- *Traffic noise*	23 %	8 %	0.003*
- *Other noise outside*	13 %	11 %	0.66
- *Noise inside*	19 %	15 %	0.45
- *Not specified*	18 %	9 %	0.06
- *No noise*	40 %	60 %	0.004*

** p level statistically significant at .05.*

Evaluation of sleep logs

The results of the sleep logs revealed that both groups reported the same levels of sleep quality; they slept rather well ($U = 51$; $p>.05$). A significant difference was found in the comparison of the sleep onset latency between both groups ($U = 19.5$; $p<0.05$). Subjects sleeping at the street side of their dwellings took on average 32.6 minutes to fall asleep compared with 12.0 minutes for the subjects sleeping at the backside.

DISCUSSION

Contrary to the outside noise levels, which were clearly distinct between both groups, no significant differences were found for the indoor noise levels in all noise indicators investigated. This finding might have some methodological implications, as in most studies, the determination of indoor noise levels relies on outside noise assessment or estimations based on outdoor measurements in reference areas (Belojević & Jakovljević 1997; Stošić et al. 2009). One of the primary interests in research on the effects of noise intrusion on sleep concerns the actual indoor noise levels, which are perceived by the subjects during the night. Having exact information on the indoor noise levels permits an establishment of direct relationships between noise exposure and sleep disturbances. The present findings suggest that caution is needed concerning this issue as the large discrepancy in outdoor noise levels between bedrooms located at the street side in comparison with the backside, is not necessarily reflected in lower noise levels reaching the inside of the bedrooms located at the backside as compared to the street side.

Although no differences in indoor noise levels were found, the results of the subjective evaluation of noise disturbances during the night revealed that subjects sleeping at the street side were significantly more disturbed by noise originating from road traffic. Furthermore, subjects sleeping at the street side had a sleep onset latency which was on average 20.6 minutes longer compared to subjects sleeping at the backside. This finding is similar with the results found in the study performed by Öhrström (1993). However, contradictory results compared with this study were found for the evaluation of sleep quality, which in our study did not differ between both groups.

As a small number of subjects participated in this study, generalizations must be drawn with caution. We can conclude from this study that the role of the outside noise on the overall perception of sleeping at the street side in noisy regions is of importance as it clearly - but indirectly as no differences in indoor noise levels were found between both groups - impacts sleep onset latency. The reported sleep quality was however not influenced by the prolonged sleep onset latency. Also, with this study we demonstrated and confirmed the importance of incorporating the bedroom location as a mediating factor of outside noise levels in the elaboration of field studies on noise and sleep disturbances. Finally, this study stresses the need for adequate indoor noise assessment as the magnitude of the difference in inside noise levels between street and backside oriented bedrooms might not be as pronounced as often assumed based on outdoor measurements and thus creates a risk for biasing interpretation of research outcomes.

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Team 6 activities from 2008 to 2011

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INTRODUCTION

Team 6 discussed the activities from 2008 to 2011 at ICBEN Congress 2008. One collaborative theme and eight individual research projects were proposed: (1) the prevalence of guidelines for reporting core information from community noise reaction surveys, (2) combined effects of noise and vibration, (3) difference in response between standardized 5-point verbal and 11-point numeric scales, (4) how to estimate noise exposure and extract dose-response relationships, (5) establishment of data archive of socio-acoustic surveys, (6) linkage with soundscape research, (7) cross-cultural surveys particularly in developing countries, (8) noise change study and (9) cooperation with Team 9. The outcomes from these activities are summarized.

TEAM 6 ACTIVITIES FROM 2008 TO 2011

Guideline for reporting core information from community noise reaction surveys

In order to precisely compare the findings and results from community noise reaction surveys, Team 6 proposed the guideline for reporting core information from socio-acoustic surveys (Fields et al. 1997) and standardized noise annoyance scales in nine languages (Fields et al. 2001), respectively. These outcomes are included in ISO TS/15666. The latter is quite successful because the scales have been used in many surveys since the publication. The scales in the other languages have also been constructed (Preis et al. 2003; Yano & Ma 2004; Kvist & Pedersen 2006; Guenther et al. 2007). However, the former is not prevalent. Thus Team 6 asked J.M. Fields to make simplified tables for core information to be shown in journal articles and conference papers. Tables 1 and 2 are those for journal articles and conference papers, respectively. We sent two tables to international researchers who are engaged in community noise reaction surveys and asked them to use these guidelines in their own, their colleagues' and their students' papers. These tables are in the homepage of ICBEN: http:www.icben.org/.

Other eight themes

In total 37 abstracts were submitted to Team 6 session. From these submissions four papers were selected for the plenary session. Community response to noise research should be carried out cross-culturally and longitudinally since community response to noise may be a function of time and space. The two studies propose annoyance models and the other two discuss cross-cultural issue of railway bonus and effects of noise change on annoyance.