Nocturnal road traffic noise and sleep: Day-by-day variability assessed by actigraphy and sleep logs during a one week sampling. Preliminary findings

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INTRODUCTION

The impact of nocturnal road traffic noise on sleep has been well documented over the past 30 years (Job 1988; Muzet 2007; Griefahn & Spreng 2004). Given the complexity of the different domains involved – sleep, noise and the individual perception – the need for further evaluation and consolidation of results still persists.

To protect people against sleep disturbances and to enhance general quality of life, the World Health Organization (Berglund et al. 2000) recommend a maximum sound level of 30 dB ($L_{Aeq,\,22\text{-}06}$) indoor for continuous background noise with individual noise events not exceeding 45 dB(A). Those recommendations have been adopted and implemented in the Brussels Capital area with a noise management plan which was created and elaborated by the Brussels Institute for Management of the Environment (BIME).

Brussels, the capital of Belgium, faces the typical issues of large cities with cultural, social and recreational programs embedded in a growing economy. A survey conducted by BIME revealed that 73 % of the Brussels inhabitants consider noise as one of the most annoying factors of environmental pollution in their city, with road traffic noise being the strongest annoying source (www.ibgebim.be). The BIME worked out an acoustic map of the city including the specific black spots of diurnal and nocturnal road traffic noise. The need for complementary, longitudinal field studies, which assess the real life impact of road traffic noise on sleep and general well being, is needed for a better understanding of the complexity of these issues and to provide local support for the current noise management plan.

Field studies have the advantage of assessing subjects in their real life situation, which is important in the study of road traffic noise effects as individual evaluation of noise is strongly influenced by context (Muzet 2007). The lack of experimental control is one of the main disadvantages of field studies. The use of actigraphy – a low cost, easy in use and low inconvenience monitoring method, appears to be a good choice for home environment studies (Sadeh & Acebo 2002). It allows registration for several consecutive nights and can be performed by the subject without help. It also permits to maintain the natural sleep and wake rhythm of the subject, so the loss of crucial information on sleep and wake habits can be reduced to a minimum. Although several empirical studies reported contradictory results in the use of actigraphy in sleep research (Sadeh & Acebo 2002; Cole et al. 1992; Paquet et al. 2007; Pollak et al. 2001), those studies mainly compared the use of actigraphy with polysomnography. Results of a longitudinal field study by Öhrström & Skånberg (2004) demonstrated that the use of a sleep log along with actigraphy can account for more reliable data. Therefore, it is strongly recommended to use a sleep log as a complementary source of information when assessing sleep with actigraphy (Sadeh & Acebo 2002; Tamura et al. 2002).

The Brussels field project

This longitudinal study investigates the relationship between road traffic noise, sleep quality and general well-being of inhabitants of the Brussels Capital Region. We will focus on specific high density road traffic noise regions, or 'black spot' regions, defined by BIME 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.ibgebim.be).*

The first part of this field study will focus on sleep quality, general well-being and stress levels of inhabitants in those black spots. This will allow us to see to what degree we can relate subjective complaints concerning sleep and general well-being with objective noise and sleep measurments. A retest situation will be carried out, approximately one year after the initial test period. We hereby are interested in finding possible habituation effects to the noise. In the second part, a control group of inhabitants of quiet regions in the Brussels Capital will be included in this study. In the last part of this project, the results of the same test protocol of two groups of commuters (by car and by public transportation) travelling between their homes and work place (Brussels) will be compared with the two Brussels groups. The main goal hereby will be to investigate if any impact caused by road traffic noise in the Brussels black spots could equal the stress and discomfort of daily commuters. We will evaluate its value as an alternative for living in the city nearby the working the place.

In this paper we focus on the first part of the study, the inhabitants of the Brussels black spots. The effect of nocturnal road traffic noise on sleep was assessed by daily sleep logs and actigraphy during 7 consecutive days. The first step in this project is to compare the subjective (sleep log) and objective (actigraphy) assessment of sleep and to investigate their relationship with nocturnal road traffic noise.

METHOD

The Brussels area and study population

Subjects were recruited in the identified black spots in Brussels. These regions were already defined and mapped by BIME. An additional screening of these areas was performed in order to avoid a maximum of confounding variables such as noise from pubs, restaurants and others.

68 % of the studied locations were apartments (apartments above the 5th floor were excluded), 27 % were enclosed houses and 5 % detached houses.

In 36 % of the places, the bedroom faced the roadside. The living room was in 77 % situated at the roadside. 86 % of the bedrooms and 81 % of the living rooms had double glazed windows.

Subjects were recruited mainly by mailing. 20 subjects (16 females, 4 males) with an average age of 44 years (ages between 24 and 62) participated. A good general health, a regular sleep-wake schedule (between 6 to 9 hours sleep per night) and having a professional activity in the Brussels Capital were the major inclusion criteria. Exclusion criteria included pregnancy, having young children, shift work, the use of hypnotics and other medication influencing alertness level. The mean average time of living in the black spots was 7,5 years.

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 periods were excluded due to the diminished road traffic volume.

Nocturnal road traffic noise

Nocturnal road traffic noise $L_{Aeq(22\text{-}08)}$ was measured inside and outside the bedroom place during 7 consecutive nights using Integrator Class 1 (inside) & 2 (outside) Sound Level Meter (Metravib). Class 1 Sound Level meter has a measurement range of 20-137 dB(A), and 30-137 dB(A) for Class 2 Sound Level Meter. Recorded noise levels were matched with the acoustic maps of the BIME. The outside sound level meters were set up according to the appropriate guidelines, taking into account the façade reflection but also safety measures for vandalism or robbery.

Noise data were analysed with a corresponding program dBTrait (version 4.805).

Assessment of sleep quality: actigraphy recordings and daily sleep log

Subjective sleep quality was assessed with daily sleep logs during 7 days, completed each morning. Questions included time to go to bed, time of lights-out, estimated sleep onset latency, wake after sleep onset time, number and reason for possible awakenings during the night and subjective morning sleep quality.

The Sensewear Armband Pro2 from Bodymedia Inc. Sensewear® was used to record body movements. A press button on the actigraph allows to put time stamps at specific events (in this study time for lights-on and lights-off). Analyses were performed with Innerview Professional 5.0. software and derived sleep parameters were: total sleep time (TST), sleep latency (SL) and wake episodes (AW).

Statistics

In this within subject design, 3 main analysis were performed: First, a repeated measures ANOVA with additional post hoc analysis was used for assessing the day-by-day variability of nocturnal road traffic noise. As 60 % of the subjects were still asleep at 7:00 am, the timeframe 22:00 pm - 08:00 am was selected.

Second, the strength of the relationship between sleep log variables and actigraph parameters is given by a Pearson product-moment correlation coefficient.

Finally, the same correlation coefficient was used to assess the relationship between road traffic noise, objective and subjective sleep measurements.

RESULTS

Nocturnal road traffic noise: assessment of day-by-day variability

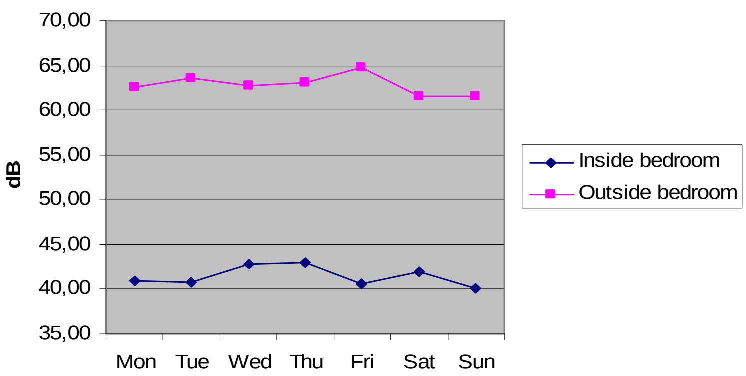

Figure 1: Evolution of nocturnal road traffic noise in black spots in the Brussels Capital ($L_{Aeq\ 22\text{-}08}$)

The evolution of nocturnal road traffic noise in the Brussels black spots is presented in Figure 1. Significant variability is found for noise outside the bedroom [$F(1,6)=0.05; p<.05$]. Post hoc analysis indicate that dB levels outside the bedroom are lower on Sunday nights in comparison with the first 3 weekdays (all $p<.05$). However, analysis of variance shows no significant day-by-day variability in road traffic noise inside the bedroom [$F(1,6)=0.65$;ns)].

Relationship between sleep log variables and actigraphy parameters

A statistically significant positive correlation between actigraphy and sleep logs for TST and SL ($r=0.64$ and $r=0.52; p<.05$) was found (see Table 1).

Table 1: Pearson Correlations between sleep log and actigraphy variables (TST: total sleep time; SL: sleep latency; AW: awakenings; act: actigraphy; log: sleep log) (*p<.05)

	TST act	SL act	AW act
TST log	*0.64**		
SL log		*0.52**	
AW log			0.11

Relationship between sleep log, actigraph and road traffic noise

The inside bedroom noise was only found to be negatively correlated with the TST of the sleep logs ($r=-0.27; p.<.05$) (see Table 2).

Table 2: Pearson Correlations between traffic noise in the bedroom with sleep variables (TST: total sleep time; SL: sleep latency; AW: awakenings; act: actigraphy; log: sleep log) (*p<.05)

	TST (log)	TST (act)	SL (log)	SL (act)	AW (log)	AW (log)
$L_{Aeq\ (22\text{-}08)}$	*-0.27**	*-0.05*	*0.11*	*0.03*	*-0.05*	*-0.07*

DISCUSSION

The noise levels were matched and found to be in the same ranges with the acoustic maps of the BIME. The levels were above those recommended by the WHO and show only a significant variation for Sunday compared with the first 3 weekdays.

Only partial correlation was found for a direct relationship between nocturnal road traffic noise and sleep measurements, with an indication that TST decreases as the noise level inside the bedroom increases. A comparison of the sleep log variables and actigraphy measurements clearly shows the need of using both types of measurements in a complementary way.

It has been shown that a fully conscious awakening during the night is seen as the strongest reaction to noise (WHO 2005). Between that one extreme on the sleep-wake continuum, a broad range of physiological reactions exists. The appearance of K-complexes in any sleep phase as registered by polysomnography can account for the most primary effect of noise disturbance on sleep (Griefahn 2002), followed by increased cortical activity, changes of sleep architecture, continuously increasing autonomic functions and body movements. It becomes clear that one doesn't have to be awakened during the night to experience the deleterious effects of noise on sleep and general well being (Passchier-Vermeer et al. 2002; Griefahn et al. 2008). Body movements assessed by actigraphy can thus provide valuable information on sleep fragmentation and noise exposure.

Another discussion point concerns the sleep wake schedule of subjects studied. Only 14 % of the subjects woke up before or at 6:00 am, 60 % were still asleep at 7:00 am. Selection criteria for participation in this study included having a professional activity in the Brussels City, which leads directly to a shorter home-work distance and possibly indirectly to a longer sleep period time. A possible extension of the morning hours proposed by the WHO ($L_{Aeq,22-06}$), could help enhance to protect against sleep disturbances caused by nocturnal road traffic noise (Öhrström 2004; Griefahn 2002). Different timeframes have been applied before in research (Passchier-Vermeer et al. 2002). It might be of interest to compare the effects of noise on sleep during the WHO proposed time frame with an extended time frame.

Further directions

The next step in the elaboration of our study is the analysis of the test-retest situation, with special emphasis on body movements and possible habituation effects.

Also, there is a need for further validation of the results. Laboratory experiments will be carried out where pre-recorded road traffic noise will be exposed to the sleeping subjects. Simultaneous PSG and actigraphic recordings will be conducted and detailed information on motility on one hand and the appearances of K-complexes on the other hand will offer a more complete picture of the impact of nocturnal road traffic noise on human sleep.

REFERENCES

Brussels Institute for Management of the Environment - BIME. www.ibgebim.be.

Berglund B, Lindvall T, Schwela DH, Goth K-T (eds.) (2000). Guidelines for community noise. Geneva: World Health Organization.

Cole RJ, Kripke DF, Gruen W, Mullaney DJ, Gillin JC (1992). Automatic sleep/wake identification from wrist actigraphy. Sleep 15: 461-469.

Griefahn B (2002). Sleep disturbances related to environmental noise. Noise & Health 4(15): 57-60.

Griefahn B, Bröde P, Marks A, Basner M (2008). Autonomic arousals related to traffic noise during sleep. Sleep 31: 569-577.

Griefahn B, Spreng M (2004). Disturbed sleep patterns and limitations of noise. Noise & Health 6(22): 27-33.

Job FRS (1988). Community response to noise: A review of factors influencing the relationship between noise exposure and reaction. J Acoust Soc Am 83: 991-1001.

Muzet A (2007). Environmental noise, sleep and health. Sleep Med Rev 11: 135-142.

Öhrström E, Skånberg A (2004). Longitudinal surveys on effects of road traffic noise: substudy assessed by wrist actigraphs and sleep logs. J Sound Vibr 272: 1097-1109.

Öhrström E (2004). Longitudinal surveys on effects of road traffic noise: effects of sleep assessed by general questionnaires and 3-day sleep logs. J Sound Vibr 276: 713-727.

Paquet J, Kawinska A, Carrier J (2007). Wake detection capacity of actigraphy during sleep. Sleep 30: 1362-1369.

Passier-Vermeer W, Vos T, Steenbekkers JHM, van der Ploeg FD, Groothuis-Oudshoorn K (2002). Sleep disturbances and aircraft noise exposure: exposure-effect relationships. Report 2002.027. Leiden: TNO Institute of Preventive Health Care.

Pollak CP, Tryon WW, Nagaraja H, Dzwoncyk R (2001). How accurately does wrist actigraphy identify the states of sleep and wakefulness? Sleep 24: 957-965.

Sadeh A, Acebo C (2002). The role of actigraphy in sleep medicine. Sleep Med Rev 6: 113-124.

Tamura Y, Horiyasu T, Sano Y (2002). Habituation of sleep to a ship's noise as determined by actigraphy and a sleep questionnaire. J Sound Vibr 250: 107-113.

World Health Organisation (2005). Report on the third meeting on night noise guidelines. Lisbon, Portugal.