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The effect of the number of aircraft noise events on sleep quality

Sabine A. Janssen [a,*], Marjolein R. Centen [a], Henk Vos [a,1], Irene van Kamp [b]

[a] Netherlands Organization for Applied Scientific Research (TNO), Department of Urban Environment and Safety, P.O. Box 49, Delft 2600 AA, The Netherlands
[b] National Institute for Public Health and the Environment (RIVM), P.O. Box 1, 3720 BA Bilthoven, The Netherlands

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ABSTRACT

Background: Both the WHO and the EC recommend the use of L_{night} as the primary indicator for sleep disturbance. Still, a key question for noise policy is whether the prediction of sleep quality could be improved by taking the number of events into account in addition to L_{night}.
Objectives: The current paper investigates the association between sleep quality and the number of aircraft noise events. The first aim of this study was to investigate whether, for the purpose of predicting sleep quality measured by motility, the nummer of events is adequately represented in L_{night} for the purpose of predicting sleep quality measured by motility. The second aim was to investigate whether the number of events at a given L_{night} has an additional predictive value. In addition, it was explored whether the total number of events should be taken into account for the production of sleep quality, or only the number of events exceeding a certain sound pressure level.
Methods: This study is based on data of a field study among 418 people living within a range of 20 km from Amsterdam Airport Schiphol. The data from this study are well suited for this purpose, since for every subject both the number and the exposure level of events are available. Sleep quality was measured by motility, derived from actimeters worn on the wrist, and by self-reported sleep quality scored on a 11-point scale. Mixed linear regression models were built in a stepwise manner to predict sleep quality during a sleep period time.
Results: The results show that, given a certain equivalent noise level, additional information on the overall number of events does not improve the prediction of sleep quality. However, the number of events above L_{Amax} of 60 dB was related to an increase in mean motility, indicating lower sleep quality. No effect of number of events was found on self-reported sleep quality.
Conclusions: This study suggests that the number of events is more or less adequately represented in L_{night} and only the number of high noise level events may have additional effects on sleep quality as measured by motility. This may be viewed as an indication that, in addition to L_{night}, the number of events with a relatively high L_{Amax} could be used as a basis for protection against noise-induced sleep disturbance.

1. Introduction

Sleep disturbance due to night time noise is a major problem for public health. Sleep disturbance is assumed to lead to short- and long-term consequences for performance, well-being and health. It is therefore important to assess the impact of noise exposure on sleep at a population level [1]. The WHO Night Noise Guidelines for Europe [2] primarily refer to relationships between health and the equivalent noise exposure at the most exposed façade during the night (L_{night}). Both the WHO [2] and the EC [3] advise on the use of L_{night} as the primary indicator for sleep disturbance. L_{night} was proposed to be a suitable noise metric, providing a considerable degree of protection against noise during sleep. However, there are indications that some aspects of sleep disturbance are additionally dependent on the number [1], character [4,5] and distribution [4] of individual noise events over the night. Previous analysis [6] on survey data [7] around Schiphol Airport showed that an increase in the number of flights was adequately reflected in the equivalent sound levels as far as annoyance was concerned. However, for sleep disturbance this could be different. The Night Noise Guidelines for Europe [2] and the END [8] allow the possible use of both the maximum sound pressure level (L_{Amax}) and sound exposure level (SEL) in addition to L_{night} to predict sleep quality.

* Corresponding author. Tel.: +31 88 866 85 51.
E-mail addresses: sabine.janssen@tno.nl (S.A. Janssen), marjoleincenten@gmail.com (M.R. Centen), Irene.van.kamp@rivm.nl (I. van Kamp).
[1] Deceased author.

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A key question for policy is whether under certain conditions and from a public health point of view, limits to L_{night} offer sufficient protection against sleep disturbance or whether additional measurements should be applied to the equivalent sound limit levels. In order to answer these questions more insight is necessary into the influence of maximum levels and number of events during the night on the degree of sleep disturbance at a given equivalent sound level.

Associations with L_{Aeq} or L_{night} have been established for self-reported sleep disturbance, mean motility [10,11] and number of awakenings [1], but for instantaneous and short term effects such as (onset of) motility, awakening, cardiovascular responses and sleep stage changes, L_{Amax} or *SEL* seem to be more predictive [2]. Since instantaneous and short term effects may also contribute to a reduction in overall sleep quality such as measured by mean motility or number of awakenings, the prediction of sleep quality may be improved by additional information on the number or levels of individual events. Taking into account the number of noise events has been shown to lead to differential predictions of sleep disturbance at a given L_{night} in simulations [1]. Theoretically, a given equivalent sound level would cause the maximum level of sleep disturbance (e.g. the highest number of awakenings or highest mean motility) when consisting of a maximum number of sound events with L_{Amax} or sound exposure level (*SEL*) just above a certain threshold to evoke a response [3]. In literature no consensus has yet been reached about the use of *SEL* or L_{Amax} for predicting effects on sleep. A somewhat dated but extensive review representing over 20 years of research on noise-induced sleep disturbance by Pearsons et al. [11] found that *SEL* was a better predictor of awakenings than was L_{Amax}, although it was vice versa for sleep stage changes. A later extensive review of the literature by Berglund et al. [12] concluded that measures of L_{Amax} are better predictors of sleep disturbances than measures of average *SEL* of events. Although the best predictor may depend on the effect of interest as well as on the type of noise source, it seems that for the prediction of sleep quality, in particular instantaneous and short term effects such as motility and awakening, it may be advantageous to take into account either the sound exposure level or maximum level (*SEL*, L_{Amax}) of events.

This paper investigates the association between sleep quality and the number of noise events based on available data from a field study among 418 people by Passchier-Vermeer et al. [10]. Previously, relationships were presented from this study between night-time aircraft noise exposure and motility for three time scales (instantaneous levels, sleep period and long term). Both *SEL* and L_{Amax} of aircraft noise events as measured inside the bedroom were found to be related to instantaneous (onset of) motility (measured by actimetry), and behavioural awakening (button push). Furthermore, sleep onset latency (SOL) and mean motility over a sleep period as measured by actimetry were shown to be associated with L_{Aeq}, while long term mean motility was associated with L_{night}. Of these measures, mean motility (both per night and over longer periods) and sleep onset latency (per night) were positively associated with indicators of subjective sleep quality and/or perceived awakenings, health complaints and adverse sleep effects. The data from this study are well suited for the present purpose, since for every subject aircraft noise exposure was measured inside the bedroom for several nights, on the basis of which both the number and the level of events could be derived. The analysis focuses on mean motility as an objective measure for sleep quality. Additionally, self-reported sleep quality is included to see whether possible effects observed on motility are also found on subjective sleep quality. The first aim of this study was to investigate if the number of events is adequately represented in L_{night} for the purpose of predicting sleep quality measured by motility. The second aim was to investigate whether, given $L_{night,}$ the number of events has an additional predictive value. It is further explored whether, for the prediction of sleep quality, the events exceeding a certain sound level should be taken into account rather than the overall number of events.

2. Methods

2.1. Data

As part of the health impact assessment around Amsterdam Airport Schiphol commissioned by the Netherlands Ministry of Housing, Spatial Planning and the Environment and in close collaboration with the Netherlands Institute for Public Health and the Environment (RIVM), a study was performed among 418 adults residing at various distances from Schiphol airport in the period of November 1999 to April 2001. The objective was to derive exposure–response relationships for night time noise effects and to estimate the prevalence of noise related sleep disturbance at a population level.

2.2. Respondents

Candidates for participating in the study were recruited by mail. The request to participate and a leaflet with information about the tasks of a subject were sent to 3000 addresses. Of these, about 540 candidates showed interest in participating, and 440 potential candidates were chosen for an intake visit and further consultation. After this intake visit 22 persons decided not to take part in the study. All 418 subjects that actually started participation completed the study. At the end of participation subjects received vouchers to the value of €113. Subjects participated from a Monday evening until a Friday morning 11 days later. After subjects agreed to participate in the study, he/she filled out an extensive questionnaire. Participation in the study encompassed the following tasks at each of the 11 participation days:

- Filling out a morning and evening diary on a laptop.
- Performing a reaction time test on a laptop before going to bed.
- Filling out a sleepiness scale five times during day and evening and wearing a watch which produced a noise signal at the times the sleepiness scale had to be filled out.
- Wearing an actimeter (CNT, type AW4, weight about 50 g) monitoring body movements continuously (with the exception of periods of bathing and swimming during study participation), and indicating bedtime and wakeup times by pressing a marker on the actimeter.
- The subjects in this study were exposed to usual night-time aircraft noise in their bedroom. Ages varied between 18 and 81 years, 50% of the subjects were male, 6% lived less than 1 year in the present neighbourhood, 44% over 15 years and the remaining 50% between 1 and 15 years.

2.3. Locations

The study was carried out successively at 15 locations within a distance of 20 km from Schiphol, selected mainly on the basis of modelled night time (23:00–06:00) aircraft noise exposure (see Fig. 1). Other selection criteria pertained to road and railway noise, degree of urbanization and type of dwelling. Two control locations were selected because of their presumed absence of night time aircraft noise to ensure a wide range of different aircraft exposures. The other locations had various degrees of night time aircraft noise exposure, from relatively few aircraft at night up to the highest exposure in residential areas close to Schiphol Airport. At each location, the study took place during two subsequent intervals