Effects of Traffic Noise on Sleep: A Review

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Abstract
Examination of the effect of noise on sleep indicated the following:

1) Views differ on habituation to noise.

2) REM sleep in all-night sleep decreases with exposure to noise. The probability of transient changes of REM sleep to other stages is low. REM sleep induction may be disturbed by noise exposure, but once it has been induced, changes to other stages or waking occur only to a small extent.

3) A transient decrease in sleep spindles is caused by noise exposure, but the number of sleep spindles for all-night sleep increases. Sleep disturbance by noise is compensated for by an increase in sleep spindles during periods of silence, possibly indicating sleep maintenance.

4) Under certain circumstances, subjective sleep is a better indicator of the effects of noise on sleep than objective sleep parameters determined by sleep polygraphy.

5) There is a linear dose-response relationship between the peak noise level and the rate of stage shift or waking. The threshold of the noise effect is about 40 dBA.

Key words: Noise, Sleep polygraphy, Subjective sleep, Dose-response relationship, Transient and all-night sleep

1. Introduction

Difficulty in falling asleep, intermittent wakefulness, light sleep, difficulty in going back to sleep, and early waking may be due to sleep disturbance. Associated factors related to the effects of noise on sleep were found in this study area to be subjective sensitivity, sex, age, health status, frequency of complaints, socioeconomic status, medication and others. The peak level, differences in peak and background levels, equivalent level (Leq), intermittence, duration and meaning of noise are all related to sleep. An intermittent high peak level of noise has a more adverse effect on health. However, comparing reesults is sometimes difficult because of the lack of standardization of exposure noise. A precise description of noise characteristics and experimental design is recommended.

Actual road traffic noise is being given studied. The effects of such noise on sleep with special emphasis on habituation, all-night and transient sleep, subjective and objective sleep, and the dose-response relationship were examined in the present study.

2. Habituation to noise

Views and opinions on this parameter differ. Thiessen et al. reported habituation to intermittent wakefulness. In their study, subjects were exposed to passing truck noise less than 20 times a night with a peak level of 65 dBA. The probability of a shift to shallower sleep and the amount of deep sleep demonstrated failure of
adaptation over 24 successive nights. The probability of awakening decreased by almost one half in two weeks. Griefahn also studied habituation of 36 students to high-density road traffic noise and detected an all-night effect of noise on sleep for 12 consecutive nights. Deep sleep was prolonged and shallow sleep including intermittent wakefulness became progressively shorter at 37 to 63.5 dBA. Vallet at al. indicate that there is no habituation to noise. According to experiments on subjects living in a noisy environment for more than four years, young subjects showed less deep sleep and older subjects, less REM sleep under conditions of silence. Both Di Nisi et al. and Öhrström reported that there seems to be no habituation to noise exposure. They exposed subjects to randomly distributed noise and it was impossible to predict either the time of exposure or the type of noise presented. Kawada and Suzuki could find no definite habituation to a noisy environment. Their interval of noise exposure was 15 minutes and there was only one pattern of passing truck noise. Essentially the same noise characteristics are reported by Thiessen, but the findings differed from each other. Based on inter-individual variation in sensitivity to noise, habituation should differ according to the person.

3. All-night and transient effects of noise on sleep: REM and sleep spindles

A decrease in slow wave sleep due to exposure to road traffic noise is indicated by several reports. The effects of noise on REM sleep still remain controversial. A decrease in REM sleep due to noise exposure is reported by some, but not by others. A field survey in which transient and all-night effects of noise on sleep were evaluated simultaneously was made in this regard. In a noisy environment, subjects were exposed to noise with a peak level of over 40 dBA more than 400 times per night, and to noise with a lower peak level about 200 times per night in a controlled environment. There was no habituation in parameters of all-night sleep but there was habitation in transient changes from REM sleep to other sleep stages. Wilkinson and Allison noted a transient decrease in REM but an increase in REM sleep for all-night sleep. The present author and colleagues confirmed REM sleep in all-night sleep to be decreased by noise exposure in an experimental room and in a field study.

Dose-response relationships between road traffic noise and sleep have been established for transient responses to road traffic noise based on studies using small numbers of subjects, although it is known that effects may vary according to the duration of road traffic noise. There are large inter-individual and intra-individual differences regarding the response to noise, which may lead to different conclusions if the number in the sample is not adequate.

To ascertain transient effects of noise on sleep, subjects were exposed to the noise of passing trucks, especially during stage 2 and REM. The threshold of noise exposure was under 45 dBA in stage 2 and over 60 dBA in REM.

In general, sleep spindles maintain sleep whose density increases, especially in the second half of all-night sleep, when the depth of sleep gradually decreases. To count the number of sleep spindles in an epoch consisting of 20 seconds, Aoki's system was used. The number of spindles per epoch decreased just after noise exposure with peak levels of 55, 60, 65 dBA. The number then recovered and the average number of spindles per epoch for the entire night increased. Compensation by sleep spindles should serve to prevent sleep disturbance due to noise.

4. Subjective and objective sleep parameters: differences in sensitivity

Wakefulness has been studied by sleep polygraphy, self-report, and through the use of a physiological movement apparatus in bed. Subjective sleep quality is self-reported the next morning using questionnaires such as OSA or
The St. Mary's hospital sleep questionnaire. A field survey in Europe, including 1,000 night data on the effects of noise on sleep suggests that a noisy environment makes subjective evaluation of sleep more difficult. Sleep disturbance by road traffic noise for subjects aged from 41 to 43 was 6.8%. Short waking periods of several minutes during night sleep may make the detection of wakefulness impossible, and deep daytime sleepiness may occur if short awakening frequently occurs. The real value self-reported sleep disturbance may thus be underestimated.

Objective sleep parameters such as sleep polygraphy data reflect primary effects on humans because information is monitored during sleep. In contrast, subjective sleep parameters reflect secondary effects on humans, because information is reported after sleep. Primary effects are usually more sensitive to noise than secondary effects. Concerning this point, the author considers secondary effects to possibly be more sensitive than primary effects. Griefahn drew a diagram of primary and secondary effects of noise on humans and the author has indicated another pathway to secondary effects without any relation to primary effects ($\text{in Figure 1}$).

### 5. Dose-response relationship and threshold of noise effects on sleep

A dose-response relationship has been demonstrated between noise peak level and objective sleep parameters. There is a linear correlation from 30 to 80 dB. The probability of waking is 18% at 50 dB and 42% at 70 dB. Thiessen found the probability of waking to be 12.7% at 47 dB and 30.6% at 60 dB. The probability of a stage shift without waking is 38% at 50 dB and 73% at 70 dB. At a peak level of 68 dBA, the stage shift over one stage is one third and the probability of waking is $1/9^{39}$. (Figure 2)

With increases in the frequency of noise stimulation, the number of stage shifts increases for 35 exposures, resulting in 3.5 awakenings on the average. More frequent stimulation decreases the waking rate. Transient alpha and delta band waves increase with the peak noise level, but delta band waves decrease for all-night sleep with noise exposure.

The threshold value of noise effects on all-night sleep is generally considered to be 40 dBA. Sleep latency becomes greater at
Fig. 2 Percentage of waking and stage shift by noise exposure (Thiessen et al.)

peak levels of 50 or 60 dBA\textsuperscript{5}. The above findings were obtained by sleep polygraphy.

6. Conclusion

The effects of noise on sleep were evaluated in relation to the following. First, the effect of all-night noise exposure on sleep differs from that of transient noise exposure. REM sleep is the most sensitive indicator of the all-night effect, but the threshold of REM to transient noise is high and REM is stable against noise exposure. Second, objective sleep parameters are generally more sensitive than subjective ones, but subjective sleep has been shown to be more sensitive than objective sleep in one case. The evaluation of noise effects on sleep should be done using both subjective and objective sleep parameters. Third, a linear dose-response relationship between noise level and sleep parameters has been reported and the threshold of the noise effect to sleep is 40 dBA.

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