

AIRCRAFT NOISE EFFECTS ON SLEEP

PRELIMINARY RESULTS ON 64 SUBJECTS AND 832 LABORATORY NIGHTS

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Introduction Sleep is vital for the recovery of physical and mental capacities. Environmental noise is a potential disrupter of the sleep process. Polysomnography (EEG, EOG, EMG) remains the gold standard for the measurement and classification of sleep. With this method noise induced changes in the normal structure of sleep may be detected in form of reductions of total sleep time (TST), shallower sleep or increments of the number of awakenings. These primary sleep disorders may lead to cognitive deficits, annoyance and mood depressions on the next day. Even long term health effects due to cumulative sleep deprivation are controversially being discussed.

Since 1999 the DLR Institute of Aerospace Medicine has been investigating the influence of nocturnal aircraft noise on sleep. 192 volunteers in total will be examined in four laboratory and two field studies. Preliminary results for the first two laboratory studies are now available. Final results are expected for the end of 2003. This paper concentrates on primary sleep disorders induced by aircraft noise.

Methods 64 healthy volunteers (aged 18-64, 25 male) spent 13 consecutive nights in our soundproof sleep facility, which is situated in the basement of the institute. 8 subjects could be examined simultaneously. Control variables were gender, age, educational, psychological and medical status, personal attitude towards aircraft noise and aircraft noise annoyance prior to the study. Each laboratory study consisted of 4 groups of 8 volunteers each, who were examined over a period of 8 weeks (4 x 13 nights). Nights 1 and 2 as well as nights 12 and 13 served as adaptation, baseline and recovery nights respectively. Lights were turned off at 2300 and again on at 0700. From nights 3 to 11 aircraft noise events with varying frequencies of occurrence (4, 8, 16, 32, 64 or 128 events with minimum intervals of 3, 7, 14, 30, 60 and 120 min respectively) and noise levels ranging from 50 to 80 dB $L_{AS,max}$ ($L_{AS,eq(3)}$ 31.2-54.5 dB, 8 hours, background $L_{AS,eq(3)}$ 30 dB) were equidistantly presented by loudspeakers. The study had a double-blinded and cross-over design. The combinations of frequency and $L_{AS,max}$ were drawn in a random fashion. In each study night always the same noise event with its characteristic $L_{AS,max}$ was presented to all 8 volunteers. 2 groups with 8 subjects each served as control groups in order to study laboratory influences and did not receive aircraft noise at all. Sleep stages were classified according to *Rechtschaffen and Kales* [1] using the signals of the electroencephalogram (EEG, C₃-A₂, C₄-A₁), electrooculogram (EOG) and electromyogram (EMG). For further details refer to the paper by A. Samel.

Results Table 1 summarizes the results of the comparison of baseline and noise nights disregarding the intensity and frequency of noise events. Both nights were standardized to the shorter sleep period time (SPT). TST decreased non-significantly by an average difference of 3.1 min in the noise nights. Slow wave sleep (SWS, sleep stages 3 and 4) was significantly reduced by 9.1 min, whereas sleep stage1 increased significantly by 3.8 min.

Sleep Stage	Baseline Nights (0) mean (SD) in min	Noise Nights (1) mean (SD) in min	Difference (1 – 0) mean \pm 95% CI (min)	p-value t-Test (Wilcoxon)
Wake	30.2 (19.9)	33.3 (16.8)	+3.1 \pm 5.9	0.306 (0.061)
S1	4.2 (4.1)	8.0 (5.5)	+3.8 \pm 2.0	0.001
S2	225.9 (33.0)	226.2 (24.1)	+0.3 \pm 7.6	0.929
S3 and S4	74.6 (32.2)	65.5 (26.3)	-9.1 \pm 5.6	0.002
REM	103.8 (25.8)	105.8 (16.0)	+1.9 \pm 6.9	0.578 (0.279)

Table 1: Distribution of sleep stages in baseline and noise nights and their differences. Comparisons are based on the shorter sleep period time (SPT). Mean values were calculated for each of the n=48 subjects in order to account for non-independent data. 395 noise and their corresponding baseline nights were analyzed in total. As the assumption of normal distributed data was denied by the Shapiro-Wilk-Test for the differences in Wake and REM non-parametric p-values derived by the Wilcoxon matched pairs signed rank sum test are also given for these categories.

The amounts of sleep stage 2 did not change at all. Wake and REM-sleep were both non-significantly increased by 3.1 min and 1.9 min respectively in the noise nights.

A logistic regression with random effects (LRA) was performed in order to be able to predict the probability of awakenings induced by aircraft noise. This probability increased significantly with $L_{AS,max}$ and time after sleep onset. It decreased as sleep deepened from sleep stage 1 to stage 4. The sensitivity for noise induced awakenings during REM-Sleep was between that of stage 3 and 4. Habituation to aircraft noise occurred as well over the 9 laboratory nights as within a single night.

Discussion Although TST was only little reduced in the noise nights compared to baseline nights, changes in sleep architecture were obvious. Amounts of SWS were significantly reduced in favor of higher amounts of sleep stage 1 and wake. Hence aircraft noise lead to a shallower sleep. With actimetry alone it would not have been possible to detect these subtle changes.

At this stage of analysis it is not possible and not intended to evaluate the preliminary results presented above: On the one hand all the data of the laboratory *and* the field studies have to be collected and analyzed, on the other hand the connection of primary and secondary noise induced sleep disorders will play an important role but has not been carried out yet.

With the LRA an important instrument for the prediction of noise induced awakenings was presented. The analysis showed that the probability of awakenings induced by aircraft noise is influenced by many moderating factors and by no means solely dependent on $L_{AS,max}$ or even L_{eq} . For a valid prediction of noise induced sleep disorders the complexity of these interactions have to be taken into account.

Keywords: sleep, noise, aircraft, awakening, logistic regression

Literature

- [1] *Rechtschaffen, A. et. al.* (1968): A Manual of Standardized Terminology, Techniques and Scoring System for Sleep Stages of Human Subjects. Public Health Service, U.S. Government, Printing Office, Washington, D.C.