The Influence of Nocturnal Aircraft Noise on Humans - a New Comprehensive Approach.

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Abstract

The DLR Institute of Aerospace Medicine in Cologne investigates the influence of nocturnal aircraft noise on human sleep and performance. 128 healthy volunteers aged 18-65 are being examined in four studies during 13 consecutive nights (2300-0700) in our sleep laboratory. The results will be validated in 2 field studies investigating 64 volunteers, thus 2496 nights in total will be observed. Various physiological signals are sampled: polysomnographic measurements (EEG, EOG, EMG), the electrocardiogram, finger pulse amplitude, respiration and actigraphy. The stress parameters cortisol, epinephrine and nor-epinephrine are extracted from nocturnal urine samples. The AGARD-Stres battery is used to examine the possible interference of aircraft noise induced sleep disturbances with mental performance. In order to measure subjective reactions, psychometric questionnaires are filled out twice a day. In 9 of the 13 nights of the laboratory studies, aircraft noise with varying frequencies of occurrence (4 to 128 events) and noise levels ranging from 50 to 80 dB $L_{AS,max}$ ($L_{AS,eq(3)}$ 31.2-52.6 dB) is presented by loudspeakers. Correct playback is assured by re-measurements of terz levels in each bedroom. The noise has been recorded in bedrooms with closed or tilted windows of residents living near an airport using a class 1 noise level meter. Since all parameters are stored simultaneously on hard disk, single noise events can be analysed and correlated with physiological parameters.

1. Introduction

In Germany the total number of commercial aircraft movements has increased about sevenfold from the early sixties until now and even higher increments are predicted for the future. Because of safety reasons a minimal interval between two starting or landing planes is crucial. Hence airport capacities during the day become more and more depleted causing the tendency of air traffic to evade to late evening, early morning or even nocturnal hours. Service providers like UPS or TNT are often dependent on nocturnal air traffic. Therefore the aircraft noise strain of residents living near airports has especially risen in these sensitive hours, even though very old and noisy planes have been removed in the early past. Despite these facts the influence of nocturnal aircraft noise on the physiology of sleep and on mental performance has not been examined adequately in the past [1].

2. Critique of the Methods of Prior Studies

There have been a lot of studies examining the influence of nocturnal road-, rail- or aircraft-noise on human sleep. But the number of primary studies measuring physiological signals as polysomnography, finger pulse amplitude, heart rate, respiration or stress hormones is small. As data sampling and analysis is time consuming and therefore expensive, the studies published so far often consist of small sample sizes and often lack of control nights. Hence statistical analysis often proves difficulty and generally valid conclusions may not be drawn. In the newest past there is the attempt to minimize operating expenses for the single examined subject in order to raise sample sizes, e.g. the substitution of the sumptuary polysomnography with actigraphy: Major disadvantages of the actigraphic assessment of sleep are:

- the percentages of deep and REM-sleep, which are very important for the restorative function of sleep, cannot be assessed properly,
- changes in the microstructure of sleep as brief arousals or minor sleep stage shifts that are not accompanied by movements cannot be detected,
- normal sleep may be accompanied by movements whereas longer periods spent awake without body movements may appear as undisturbed sleep.

3. Methods and Study Design

For these reasons, the DLR Institute of Aerospace Medicine investigates the influence of nocturnal aircraft noise on human physiology and psychology. 128 healthy volunteers aged 18-65 years will each be examined for thirteen consecutive nights in our soundproof sleep facility (area about 300 m^2), which is situated in the basement of the institute and where 8 volunteers can be examined simultaneously.

Control variables are gender, age, educational, psychological and medical status, personal attitude towards aircraft noise and the usual environmental load caused by aircraft noise in the volunteer's residential area. 4 groups of each 8 volunteers are examined over a period of 8 weeks (4 x 13 nights). Nights 1 and 2 as well as nights 12 and 13 serve as adaptation, baseline and recovery nights, respectively (see figure 1).

		study night												
		1	2	3	4	5	6	7	8	9	10	11	12	13
study period	I	0	0	0	0	0	0	0	0	0	0	0	0	0
	II	0	0	N	N	N	N	N	N	N	N	N	0	0
	III	0	0	N	N	N	N	N	N	N	N	N	0	0
	IV	0	0	N	N	N	N	N	N	N	N	N	0	0

Figure 1: Overview of the first laboratory study. Each group consists of 8 volunteers who sleep for 13 consecutive nights in our sleep facility. N = nights with aircraft noise, 0 = silent control nights.

Lights are turned off at 2300, and set again at 0700. In the noise nights equidistant 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 $L_{AS,max}$ (that corresponds to $L_{AS,eq(3)}$ 31.2-54.5 dB, 8 hours, background $L_{AS,eq(3)}$ 30 dB) are presented by loudspeakers. The combinations of frequency and $L_{AS,max}$ (see figure 2) over the 9 noise nights are drawn in a random fashion. It is our goal that each of the cells in figure 2 consists of at least 32 study nights (16 nights with noise events of starting and 16 with noise events of landing aircrafts). In each study night always the same noise event with its characteristic $L_{AS,max}$ is presented to all 8 volunteers.

frequency of occurrence [/8h]

$L_{AS,max}$ [db]	4	8	16	32	64	128
50			24	24	32	24
55	24	32	24	24	24	24
60	24	32	24	24	24	
65	24	24	24	24	24	
70	24	24	24	24		
75	24	24	24			
80	24	24				

Figure 2: Combinations of frequency of occurrence and $L_{AS,max}$ of aircraft noise events used in the first three of four laboratory studies.

Correct playback is assured by re-measurements of terz levels in each bedroom. The noise has been recorded in bedrooms with closed or tilted windows of residents living near the airport using a class 1 noise level meter. Since all parameters are stored simultaneously on hard disk, for the first time analysis and correlation of single noise events with physiological parameters with a maximum resolution of 5 ms can be performed. So far 96 volunteers (3 x 4 x 8) have been investigated accumulating 1248 nights. 2 groups (as in study period 1 in figure 1) served as control groups to study laboratory influences, and did not receive aircraft noise at all. The following physiological parameters are examined during the night:

- polysomnography (EEG, 2 x EOG, 2 x EMG)
- actigraphy (24 h)
- ECG
- respiration (movements of the rib cage, nasal and oral air flow)
- finger pulse amplitude
- body position

Urine is collected over the whole sleeping period for subsequent analysis of stress hormones (cortisol, epinephrine, nor-epinephrine) and electrolytes.

Both in the evening and in the morning different questionnaires have to be filled out to investigate the influence of aircraft noise on psychological processes as the process of recreation, annoyance or subjective sleep measures.

Furthermore, at these times a mental performance test, the so called AGARD-Stres-battery [2], is completed by the volunteers.

The test consists of:

- memory and search tasks with 4 or 6 letters
- unstable tracking task
- single reaction time task

The results of the laboratory studies will be validated in two field studies consisting of 64 volunteers in total.

Conclusions

The DLR Institute of Aerospace Medicine investigates the influence of aircraft noise on human sleep and performance in 4 laboratory studies consisting of 128 volunteers and 1664 study nights. The results will be validated in 2 field studies consisting of 64 volunteers and 832 study nights. These data will serve us to deliver statistically proven results to provide recommendations for industry, planners and legislative bodies. Data acquisition and analysis will be finished by the end of 2003, although some preliminary results of the first two laboratory studies consisting of 64 subjects and 832 study nights have already been published [3].

References

1. Basner, M. et al.: “Wirkung von Nachtfluglärm auf den Schlaf - ein neuer Forschungsansatz.", Zeitschrift für Lärmbekämpfung, 2000(47): 201-205
2. Santucci, G. et al.: “Human performance methods." AGARDograph No 309, NATO-AGARD, Neuilly-sur-Seine 1989
3. Basner, M. et al.: “Nachtfluglärmwirkungen – eine Teilauswertung von 64 Versuchspersonen in 832 Schlaflabornächten.”, DLR-Forschungsbericht FB 26-01, ISSN 1434-8454, Köln, 2001 (www.me.kp.dlr.de/me-fp/deutsch/fluglaerm/literatur.htm)