

# ANNOYANCE FROM NOCTURNAL AIRCRAFT NOISE

## SIGNIFICANCE OF NUMBER OF EVENTS AND MAXIMUM LEVELS

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**Introduction** Annoyance is the most important psychological effect of environmental noise exposure. People's annoyance reaction to traffic noise is primarily caused by noise-induced sleep disturbances. Thus, aircraft noise exposure during sleep may cause increased annoyance. Even though sound energy emitted by individual aircrafts has drastically been reduced in the past - particularly due to the replacement of older and loud aircrafts -, often more than 100 aircraft noise events per night are registered close to residential areas leading to an increased extent of resident's annoyance. For noise with intermittent character such as aircraft noise, the number of events and maximum noise levels ( $L_{AS,max}$ ) are better related to annoyance than the equivalent noise levels ( $L_{AS,eq}$ ) [1]. A number of field studies on aircraft noise were undertaken in the 1970s and 1980s to evaluate their relative importance regarding annoyance [2-5]. In summary, annoyance was more or less significantly related to both parameters. Critical thresholds were defined but the outcomes are ambiguous. Hence, it was intended to specify again the significance of both factors, the number of events and maximum noise levels with respect to annoyance. The analysis presented here is part of a long-term project conducted by the DLR Institute of Aerospace Medicine that investigates the influence of nocturnal aircraft noise on human sleep, performance and sensation by means of extensive laboratory and field studies. It is integrated in the HGF/DLR project "Quiet Air Traffic" applying an innovative research approach to determine valid criteria for human-specific effects of nocturnal aircraft noise.

**Methods** Three laboratory studies were performed in an isolation facility (AMSAN) with eight sleeping cabins under controlled conditions but close to reality. The experiments had a unbalanced double blind, crossover design. Thirty-two healthy participants with normal hearing abilities were chosen for each investigation (altogether 58 females and 38 males aged 18 to 65 years). The 32 participants of each experiment were divided into four subgroups of eight subjects who were simultaneously studied for 13 consecutive nights. A control group of 16 persons did not receive any aircraft noise. Nights one and two served for adaptation and baseline and were free from noise. Nights 12 and 13 were recovery and additional control nights without noise. In the remaining nine nights, aircraft noise events with a varying distribution of number of events and maximum noise level were presented to the subjects in the acoustically calibrated sleeping rooms. The noises were played back with equidistant intervals between 11:15 p.m. and 6:45 a.m. The  $L_{AS,max}$  of the individual aircraft noises ranged from 50 to 80 dB near the ear of the sleeping subject (indoor level). The frequency of occurrence lied between 4 and 128 per night. These combinations led to  $L_{AS,eq}$  from 31,2 up to 54,5 dB(A) containing a constant background level of 30 dB(A) caused by the AC-unit. In the morning each subject filled in a questionnaire on individual's night sleep and subjective noise sensations. Annoyance due to nocturnal aircraft noise was evaluated using a 5-point rating scale ranging from "1 = not annoyed" to "5 = very annoyed".

**Results** Kruskal-Wallis one-way analysis of variance and Man-Whitney tests for independent samples were used to determine differences between levels of noise and frequency. First, an-

noyance is significantly increased in the morning after nights with different noise exposure compared with quiet control nights. Regarding the noisy nights annoyance is significantly affected by both, number of events and maximum noise levels. However, at 128 aircrafts per night and higher  $L_{AS,max}$  (70-80 dB(A)) the significant effect of both parameters exists no longer. This is probably due to the unbalanced experimental design, i.e. extreme combinations of maximum noise levels and frequency of occurrence (e.g. 4 x 50 dB(A) or 128 x 80 dB(A)) were not included due to ethic motives and reasons of ecological validity. The impact of number of events and noise levels on annoyance seems to be dependent. At lower frequencies of four and eight aircrafts per night,  $L_{AS,max}$  of at least 55 up to 65 dB(A) affect annoyance significantly. At higher frequencies between 16 and 64 noise events per night at least 50 up to 65 dB(A) have a significant influence on annoyance. In this range annoyance grows significantly with increasing number of aircrafts events and peak noise levels.

**Discussion** Taken together, results from this analysis support the conclusion that both number of aircraft and maximum noise levels are important in order to express annoyance resulting from aircraft noise exposure during sleep. This effect grows with an increase of number and noise levels. Peak noises and frequency of occurrence are dependent variables for aircraft noise annoyance. The critical value of noise events per night seems to be between four and eight at a maximum noise level of at least 55 up to 65 dB(A) and at 16, 32 and 64 aircraft events for a minimum of 50 up to 65 dB(A). At higher noise levels of 70 to 80 dB(A), and 128 noises per night no significant impact of both parameters was found. This is most likely due to the unbalanced experimental design. Data suggest that actions to control the annoying effects of nocturnal aircraft noise should focus on noisy aircraft types with moderate to high peak levels and that limiting the number of aircrafts will have an influence on the extent of annoyance. These preliminary criteria ascertained from the three laboratory experiments have been validated in two extensive field studies.

**Keywords:** annoyance, nocturnal aircraft noise, number of events, maximum noise levels

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