AIRCRAFT NOISE AND SLEEP DISTURBANCE: A FIELD STUDY

C J Jones and J B Ollerhead.
Civil Aviation Authority, London.

1. Introduction.

Rising demand for air transport is bringing increased pressure for more aircraft movements at night in order to make fuller use of existing airport capacity. But public acceptance of night traffic is low; it has long been held by environmental groups that people are especially sensitive to noise at night and that sleep disturbance is a particularly harmful effect of environmental noise. In recognition of this the UK Government has implemented "night restrictions" policies which limit aircraft movements at Heathrow and Gatwick Airports.

Any future changes to the night restriction policies at Heathrow and Gatwick need to be supported by reliable scientific evidence as to the likely environmental effects. Accordingly, the Department of Transport asked the Civil Aviation Authority to undertake a major study of aircraft noise and sleep disturbance.

This paper outlines the approach which was taken to this study and describes the experimental work which was carried out; the results of the work are still being analysed so the details of the findings of the study are not yet available.

2. Approach to The Study.

The basic evidence which supports present night restrictions policy relied on self-reports of sleep quality, obtained by interviewing people in social surveys. These are subjective rather than objective criteria; there is a need to establish objectively a correlation between specific noise events and any consequent sleep disturbance. One evident means of doing this is to measure directly both the noise stimuli and any immediate disturbance to sleep.

Sleep disturbance, like other reactions to noise, varies greatly from person to person, so the extraction of valid 'dose-response' relationships requires statistical analysis of suitably large data samples. There is a substantial body of research in which the sleep disturbance of people due to different noise exposures have been measured under laboratory conditions; a much smaller number of studies have been carried out under 'field' conditions, ie whilst people sleep in their own homes. Unfortunately, there is evidence of a substantial lack of agreement between field and laboratory data; a recent reanalysis of available data [1] indicates that people are actually much less likely to be awakened, by the same level of noise, at home than in the laboratory. It was therefore concluded that a new laboratory study may not add significantly to existing knowledge and that the best approach would be a large scale field study.

Electroencephalography (EEG) measurements have been widely used to monitor sleep disturbance. However, EEG measurement, especially in people's homes, is complex and therefore expensive, which implies a difficulty in obtaining data in large quantities. Alternative indications of sleep disturbance have often been obtained from measurements of people's night-time limb movements. One means of obtaining the measurements is by the use of activity monitors, or actimeters, piezoelectric devices which measure, for example, wrist movement. Actimetry measurements can be made relatively inexpensively with small self-powered data loggers, which can operate without attention for several weeks. It is relatively straightforward to carry out actimetry measurements on a large sample of subjects, along with simultaneous measurements of aircraft noise levels and other factors which could affect sleep. In several applications [2, 3] actimetry measurements have shown a good correlation with EEG measures of awakening.

Although the practical benefits of actimetry are recognised, its validity and applicability to the question of sleep disturbance due to aircraft noise had not previously been demonstrated in a large scale experiment. Any use of this technique would therefore need to be subject to verification by comparison with the 'gold standard' of EEG measurements. Following a pilot study to evaluate actimetry by comparing it with EEG measurements, it was decided that the best approach would be to monitor all the study subjects using actimetry, with a small sub-sample of subjects also being monitored simultaneously using the EEG technique; thus enabling the actimetry data to be 'calibrated' against the EEG records.

3. Site Selection.

Heathrow, Gatwick and Manchester Airports have the highest nightly aircraft movements in the UK; study areas were therefore required at these three airports and also at Stansted, London's 'third' airport. Figure 1 shows the pattern of available study areas at the four airports in relation to the main night noise variables: eight hour equivalent continuous aircraft sound level (Leq, dB(A)); average sound exposure level (SEL, dB(A)); number of aircraft events and predominant mode (arrivals or departures).

From the available areas eight were selected for inclusion within the study, see Table 1. The basis for selection was that the 'site' must contain sufficient homes to provide the necessary samples of subjects, yet be small enough to be considered a 'constant noise area' (ie with aircraft noise exposures being relatively uniform over the whole site). In addition, it was necessary that the eight sites provided a wide range of nighttime aircraft noise exposures.

4. Fieldwork: Methodology.

For each of the eight sites the fieldwork involved:

a) Social survey interviews of 200 respondents. The purposes were: to provide a pool of people from which to select the actimetry subjects; to provide socio-psychological data as a basis for investigating the effects of intervening factors on sleep disturbance and to allow comparison with previous social survey studies of sleep disturbance.

b) Selection of 50 subjects (from the social survey respondents) to take part in the actimetry monitoring. 15 nights of actimetry were carried out on each of the 50 subjects. After each night's monitoring each subject completed a sleep log on which they noted information such as what time they went to bed/got up and if they slept with their windows open. During the monitoring period the subjects also completed reports at 2 hour intervals during the day to give an indication of how alert/sleepy they felt.

c) Carrying out EEG monitoring on 6 of the 50 actimetry subjects for 4 nights (simultaneous with actimetry measurements).

d) Outside noise measurements at locations around the study area. Portable noise monitoring units recorded aircraft noise levels and background noise statistics within each study area (usually in domestic gardens). Some noise measurements were also made inside typical dwellings within the study areas.

5. Fieldwork: Results.

Social Survey.

Altogether, nearly 4000 addresses in the eight study sites were targeted and a total of 1636 initial interviews were conducted, with more than 200 at each site.

Aircraft Noise Measurements.

During the study 4823 aircraft noise events were logged (in terms of event Leq, maximum A-weighted sound level (LAmax) and SEL) for correlation with the sleep measurement data. A summary of the measured noise data is given in Table 2.

The night-average aircraft noise variables are compared with the targeted values in Figure 2. In this graph the average SEL is plotted against average hourly number of events - for the 8-hour period 2300-0700 - at each of the sites. Except at the Manchester sites, where the numbers of events were a little higher, the traffic was lower than expected, particularly at Gatwick where the shortfall was more than 30%. This is attributed to the effects of the 1991 economic climate.

Sleep Measurements.

Full complements of subjects were recruited at all sites and, overall, both EEG and actimetry measurement programmes progressed very satisfactorily and nearly 50,000 subject-hours of sleep data were recorded.

6. Data Analysis.

The main analysis tasks are to investigate the relationships between:

(i) EEG and actigraph responses to validate the disturbance criteria.

(ii) Actigraph measured disturbance and aircraft noise events.

(iii EEG responses and aircraft noise events.

(iv) Social survey responses, measured sleep disturbance and noise.

These analyses are now in progress and the early results should be available for presentation at the conference. The results of this major study should provide a significant addition to present knowledge on the impact of aircraft noise on people.

Acknowledgements.

This research is being undertaken on behalf of the Department of Transport by the Civil Aviation Authority with the specialist help of teams from Loughborough University, Manchester Polytechnic and Southampton University led respectively by Professor J Horne, Dr K Hume and Dr I Diamond. Advice on all aspects of the study has also been obtained from a group of international experts on sleep.

References.

1 K S Pearsons et al.
Analyses of the predictability of noise-induced sleep disturbance.
US Air Force (Human Systems Division, Brooks AFB) Report HSD-TR-89-029, 1989.

2 J B Webster, D F Kripke
An activity-based sleep monitor for ambulatory use.
Sleep 5(4), 389-399, 1982.

3 A Sadeh et al.
Actigraphically based automatic bedtime sleep-wake scoring: validity and clinical applications.
J. Ambulatory Monitoring 2(3), 209-216, 1989.

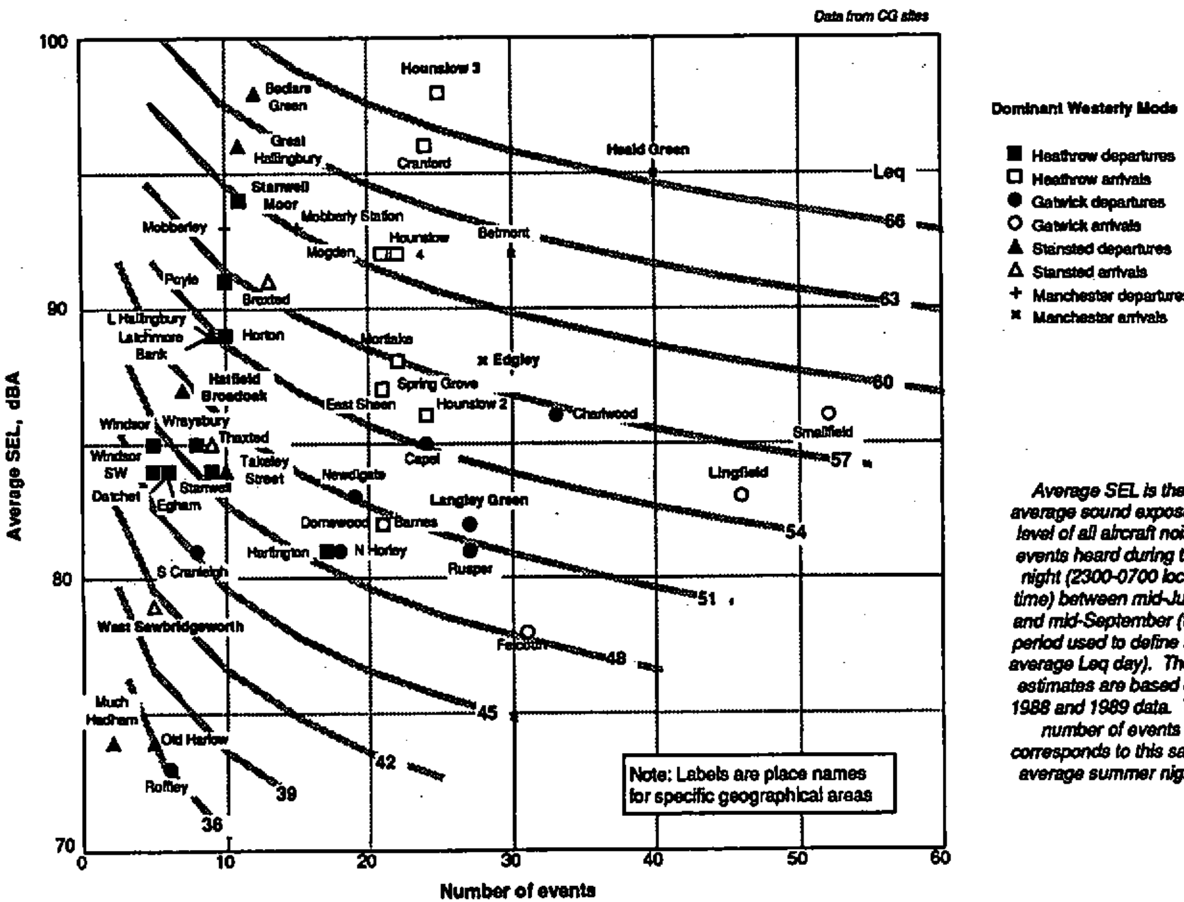
TABLE 1: SITES SELECTED FOR INCLUSION IN STUDY

Site Code	Site Name	Airport
A	Hounslow	Heathrow
B	Langley Green	Gatwick
C	Stanwell Moor	Heathrow
D	Lingfield	Gatwick
E	Heald Green	Manchester
F	Edgeley	Manchester
G	Hatield Heath and Hatfield Broad Oak	Stansted
H	West Sawbridgeworth	Stansted

TABLE 2: SUMMARY OF EXTERIOR AIRCRAFT NOISE EVENTS

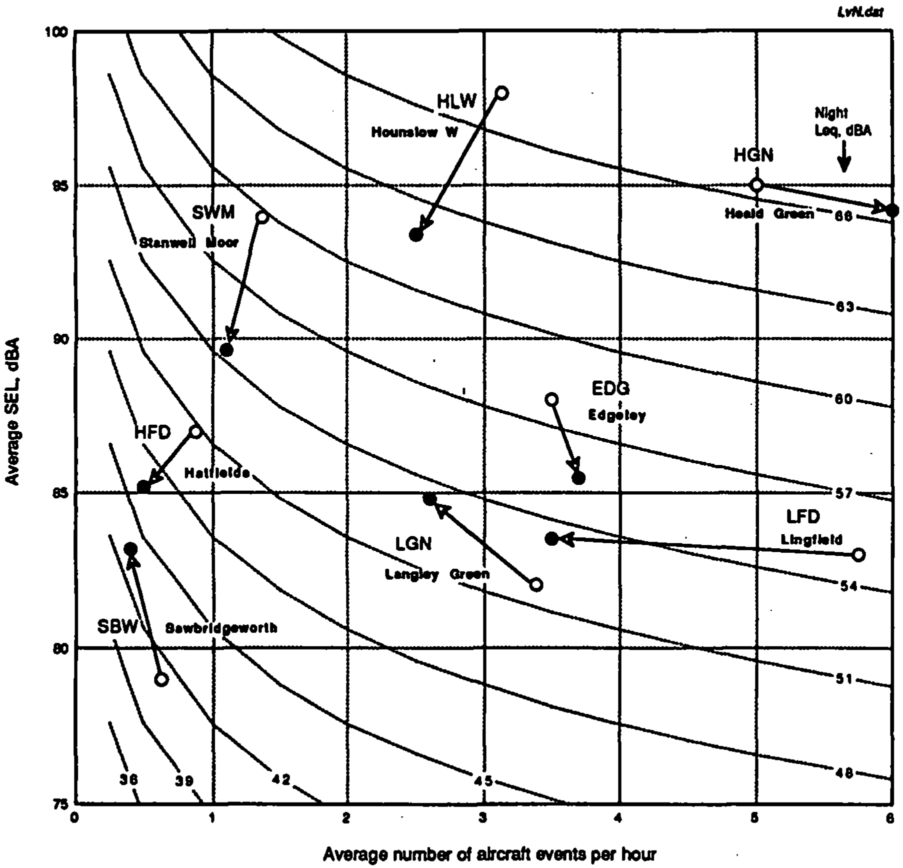
SITE	Total No. of Nights	Ave LAmax	Total events	Ave SEL	Total Aircraft Leq
2200 to 0800 (local time)					
A	15	84.2	670	92.1	63.1
B	15	75.2	706	85.6	56.6
C	15	82.4	656	91.6	62.5
D	15	74	734	83.9	55.3
E	15	87.8	1188	94.4	67.8
F	13.5	76.7	633	86.2	57.3
G	15	74	150	85.0	49.4
H	15	73.4	86	84.0	46.0
2300 to 0700 (local time)					
A	15	85.8	301	93.4	61.8
B	15	74.0	312	84.8	53.3
C	15	80.7	130	89.6	54.4
D	15	73.4	426	83.5	53.4
E	15	87.6	729	94.2	66.5
F	13.5	76.2	399	85.5	55.6
G	15	74.2	58	85.2	46.5
H	15	72.2	47	83.2	43.6
0000 to 0600 (local time)					
A	15	85.7	102	93.6	58.6
B	15	70.1	91	79.7	44.1
C	15	76.7	21	87.2	45.3
D	15	73.1	219	83.0	51.3
E	15	87.7	446	94.5	65.9
F	13.5	76.3	266	85.7	55.3
G	15	72.4	33	83.5	43.6
H	15	70.7	26	81.6	40.7

NOTES:
Total events - Number of aircraft noise events ≥ 60 dBA
Ave LAmax - logarithmic average LAmax of all aircraft events ≥ 60 dBA
Ave SEL - logarithmic average SEL of all aircraft events ≥ 60 dBA
Total Aircraft Leq - aircraft noise Leq over total number of nights at each site



Average SEL is the average sound exposure level of all aircraft noise events heard during the night (2300-0700 local time) between mid-June and mid-September (the period used to define the average Leq day). These estimates are based on 1988 and 1989 data. The number of events corresponds to this same average summer night.

FIGURE 1 POSSIBLE STUDY AREAS (NIGHT NOISE EXPOSURES - 2300-0700)



The open symbols are the original 8-hr (2300-0700) estimates (Average mode)

The solid symbols are actual 8-hour (2300-0700) values estimated from measured data (probably subject to minor revision)

FIGURE 2: SLEEP SITE NOISE EXPOSURE ESTIMATES