

inter.noise 2000
The 29th International Congress and Exhibition on Noise Control Engineering
27-30 August 2000, Nice, FRANCE

I-INCE Classification: 6.0

NIGHT-TIME AIRCRAFT NOISE AND SLEEP - THE 1999 UK TRIAL METHODOLOGY STUDY USING BOTH FIELD AND LABORATORY METHODS

K. Robertson*, I. Flindell, M. Jiggins***, N. Wright****, C. Turner******

* DERA Centre for Human Sciences, DERA, GU14 0LX, Farnborough, United Kingdom

** Institute of Sound and Vibration Research, University of Southampton, SO17 1BY, Southampton, United Kingdom

*** National Physical Laboratory, Teddington, TW11 0LW, London, United Kingdom

**** Centre for Human Sciences, DERA, GU14 0LX, Farnborough, United Kingdom

Tel.: +44 1252 393339 / Fax: +44 1252 392097 / Email: karobertson@dera.gov.uk

Keywords:
AIRCRAFT NOISE, SLEEP, FIELD AND LABORATORY

ABSTRACT
The 1999 UK Trial Methodology Study was commissioned by the UK Government to assist it in arriving at an informed decision on whether or not to proceed to a full-scale sleep study. The trial methodology study addressed the feasibility of studying differences in 'shoulder hours' noise exposure by using a combined field and laboratory method, it investigated possible differences in sleep patterns between 'high' and 'lower' aircraft noise exposed communities, and it looked at self-reported noise sensitive people. There were a number of interesting findings which indicate the potential of the combined field and laboratory method.

1 - INTRODUCTION
In February 1998, the UK Department of the Environment, Transport, and the Regions (DETR) announced a Government Commitment to carry out "*a research trial on sleep disturbance. Its aim will be to assess methodology and analytical techniques, to determine whether to proceed to a full scale study of either sleep prevention or total sleep loss*". DETR invited tenders for a research study with the following objectives:
"*To evaluate the research options A-C and to recommend the best way to proceed for any future full scale study of sleep disturbance and other effects of night-time aircraft noise:*

- *To 'extend' the 1992 UK Field Study to the shoulder hours (23:00-23:30 and 06:00 − 07:00);*
- *To compare sleep patterns in 'high noise' and 'low noise' communities;*
- *To study sleep disturbance among noise sensitive people*".

A consortium comprising the Institute of Sound and Vibration Research at the University of Southampton, the Centre for Human Sciences at DERA Farnborough, the Centre for Mechanical and Acoustical Metrology at the National Physical Laboratory and the MVA Consultancy at Working were contracted to carry out the study.

2 - BACKGROUND
A large scale field study of aircraft noise and sleep disturbance around major UK airports was carried out by a consortium lead by the CAA for the Department of Transport in 1991. This study was reported in December 1992 [1], and is usually referred to as the 1992 UK Field Study. This study found a low incidence of objectively measurable sleep disturbance (both minor arousals and brief awakenings from

persistent sleep) attributable to individual aircraft events. There was no detectable increase in the probability of minor arousals or brief awakenings for outdoor aircraft noise event levels below 80 L_{Amax}. For outdoor aircraft noise event levels above 80 L_{Amax}, the probability of a minor arousal was around 1 in 30 and the probability of a brief awakening was around 1 in 75 (Note: these probabilities are additional to the probability of a minor arousal or a brief awakening occurring at around the same time as, but not caused by, the aircraft noise event).

Notwithstanding these findings of a relatively low incidence of objectively measurable disturbance, aircraft noise at night remains an issue of public concern around major UK airports. Because of this, airport residents groups have described the findings of the 1992 UK Field Study as being counter-intuitive. In addition, research studies carried out in laboratories have generally found higher sensitivity to noise at night than was observed in the 1992 UK Field Study. The most recent international guidance on noise levels likely to avoid sleep disturbance [2] recommends values of 45 L_{Amax} measured indoors, with lower values preferred where the background noise levels are low or to protect the most noise sensitive persons. The outdoor aircraft noise event threshold of 80 L_{Amax} found in the 1992 UK Field Study can be roughly equated to anything from 45 to 60 L_{Amax} indoors depending on outdoor to indoor attenuation which varies with different house constructions, with different types of windows, and whether the windows are open or closed.

The main motivation behind the 1999 UK Trial Methodology Study was to explore the feasibility of being able to resolve some of these outstanding issues. Following extensive consultation, the three research options A-C were defined by NATS Ltd. *Option A – to 'extend' the 1992 UK Field Study to the shoulder hours* refers to the possibility of aircraft noise at the beginning and end of the night period (commonly known as the night shoulder hours) contributing to delayed sleep onset and premature awakening. These two possibilities were not specifically addressed by the design of the 1992 UK Field Study, which mainly investigated arousals and awakenings whilst asleep. *Option B – to compare sleep patterns in 'high noise' and 'low noise' communities* refers to a requirement for some overall measure of sleep quality or loss of sleep which could be related to objectively measurable next-day effects and which might show differences between 'high noise' and 'low noise' communities. The main focus of the 1992 UK Field Study was disturbance caused by separate events rather than overall sleep measures. *Option C – to study sleep disturbance among noise sensitive people* arose from previous findings that there is a wide range of individual sensitivities to noise at night. In terms of research feasibility, it was considered important to be able to deal with individual differences in noise sensitivity as a separate issue.

The consortium proposed that research options A, B, and C be investigated by a combined laboratory and field approach. However, the validity of using this methodology needed to be established by direct comparison of laboratory findings against data obtained in people's own homes. The chief advantage of the laboratory method is that all exposure variables can be precisely controlled in accordance with a rigid experimental design. Also, additional procedures and measurements are feasible in the laboratory which would not be practicable under field conditions. The main potential disadvantage is that subjects might not behave in the same way in the laboratory as they do in their own homes. The laboratory is to some extent artificial and subjects might not have time to habituate either to the unusual environment or to the noise exposure.

3 - PROCEDURES

The research was carried out in two phases; the first phase being a field trial in residential areas around Manchester Airport; with the second phase being a laboratory study completed in the sleep laboratory at DERA Farnborough with the noise exposures being closely matched to those measured in Manchester. During both phases, sleep electroencephalography (EEG), actigraphy (similar devices to those used in the 1992 UK Field Study) and other physiological measurements were taken, together with a battery of subjective reports and next-day performance tests. For the field study, indoor and outdoor noise measurements were taken and the indoor measurements were simultaneously recorded on the EEG recorders. In the laboratory it was also possible to carry out the multiple sleep latency test (MSLT) at regular intervals the following day as an objective measure of daytime sleepiness. It is not practical to use the MSLT under field conditions. Trained interviewers using a structured questionnaire, in accordance with agreed constraints, recruited all volunteers aged between 30-40 years. To meet research option C, only those subjects who reported themselves as '*more sensitive to aircraft noise at night than the average person*' were invited to take part.

For the field phase, 9 subjects were recruited from predefined 'high noise' and 'lower noise' areas near to Manchester Airport (i.e. 18 subjects in total). The 'high noise' area was defined by named streets in Moss Nook and Heald Green at 500 m to 2500 m from the landing runway threshold and was therefore representative of the higher levels of residential aircraft noise exposure around Manchester Airport. The 'lower noise' area was defined by named streets in Cheadle and Edgeley at 4000 m to 7000 m from the landing runway threshold. These areas were selected because outdoor aircraft noise exposure was expected to be significantly lower than in the defined 'high noise' area, while still being high enough above other background noise sources to allow for reliable measurements. It should be noted that as a trial methodology study, this study was not intended to be capable of deriving noise dose-effect relationships. Subjects participated in the trial on consecutive nights from Sunday until Thursday. The first test night for each subject was considered an adaptation night. Each evening subjects were collected and taken to a temporary laboratory at an hotel close to Manchester Airport to be instrumented with the necessary recording equipment. They then returned to their own houses with instructions to go to bed at their normal time. The recording equipment was collected from their houses the next morning for downloading data and checking ready for use the following night.

For the laboratory phase, 9 additional subjects were recruited from residential areas in and around Farnborough with generally similar characteristics to the Manchester areas. Each subject attended the laboratory one night a week for a period of 5 weeks. The first test night was an adaptation night so that subjects were familiar with the recording techniques. On the four subsequent occasions subjects were exposed in a balanced order to the following test conditions: a zero aircraft noise condition; a Manchester 'high noise' simulation night with recorded aircraft flyover events reproduced using loudspeakers; and two further experimental nights with the numbers of aircraft noise events doubled in either the evening or early morning shoulder hours (specifically to address research option A). (Note: to increase the likelihood of obtaining statistically significant differences in sleep measures, the duration of the shoulder hours periods were doubled from the standard definitions, i.e. evening shoulder hour from 23:00 to 24:00 and early morning shoulder hours from 05:00 to 07:00).

4 - FINDINGS

4.1 - Airport traffic and average noise levels during the study

As far as is known, all aircraft movements over the field study areas during the period of the study were arrivals from the north-east. Due to the prevailing wind direction, this is the predominant operating pattern at Manchester Airport although aircraft depart over the field study areas whenever there are north-easterly winds. The average number of arrivals reduced from around 10 per hour between 22:00 to 23:00 hrs down to around 2 to 3 per hour during the quietest part of the night from 00:00 hrs to around 04:00 hrs. After 04:00 hrs the average number of arrivals increased again reaching morning peaks of around 8 per hour between 06:00 to 07:00 hrs and around 14 per hour between 07:00 to 08:00 hrs. The daytime peaks of up to around 24 arrivals per hour were between 08:00 to 09:00 hrs and again between 17:00 to 18:00 hrs. Measured over the field study nights, the average number of arrivals during the 23:00 to 07:00 hrs night period was 36.6 but there was considerable variation from one night to the next (range 27 to 45).

Average outdoor aircraft noise event sound levels were 82.3 L_{Amax} in Moss Nook, 78.3 L_{Amax} in Heald Green and 76.7 L_{Amax} in Cheadle/Edgeley. The corresponding average indoor aircraft noise event sound levels were 51.9 L_{Amax} in Moss Nook, 52.1 in Heald Green and 52.1 in Cheadle/Edgeley. The average outdoor to indoor sound level differences were 32.2 dBA with the windows closed (9 subjects) and 27.3 dBA with the windows open (9 subjects). It should be noted that while these average outdoor aircraft noise event sound levels are not particularly high when compared against the 80 L_{Amax} threshold identified in the 1992 UK Field Study, there was considerable variation above and below the averages with some outdoor aircraft noise events at much higher (and lower) sound levels.

4.2 - Field study

Overall, no major differences were observed between sleep variables from participants in the 'high noise' and 'lower noise' areas. There were some differences in general noise sensitivity ratings, in self reported anxiety ratings and in some detailed EEG measures. No differences were observed in next day performance measures. However, it should be noted that there were no significant differences between the average indoor aircraft event noise levels as measured in the 'high noise' and 'lower noise' areas. This was partly because the average outdoor to indoor attenuation in the 'high noise' area was greater than in the 'lower noise' area but also because there were unexpectedly small differences in the level of outdoor aircraft noise events. If there had been a significant difference in indoor aircraft noise event levels then significant differences in sleep outcome measures might well have occurred.

There were increases in the number of awakenings, total durations of stage 1 sleep, number of rapid eye movement (REM) sleep periods and changes in the frequency content of the EEG associated with higher numbers of aircraft noise events occurring during the 'lights out' period. It was not possible within the limitations of a small-scale trial methodology study to determine the underlying importance of these findings. They could have been indicative of an effect of the number of aircraft noise events occurring during the night as a whole. However, some subjects who stayed in bed longer in the mornings would have been exposed to much higher numbers of aircraft noise events and this could have influenced the quality of sleep.

4.3 - Laboratory study

The average noise sensitivity ratings were in the same range as the field study. There was generally good agreement between the laboratory and field results. The numbers of awakenings detected by standard visual analysis of the EEG records was very similar to the numbers observed in the field. Both sets of data were also consistent with the 1992 UK Field Study results. Although the numbers of actual awakenings in the laboratory and in the field were generally similar, the numbers of reported awakenings (reported using a next-day questionnaire) were greater in the laboratory (between 4 and 8 per night, depending on test condition) than in the field (around 2 per night and not significantly different between the 'high noise' and 'lower noise' areas).

Comparing the four aircraft noise event conditions tested in the laboratory, there were no differences in next day effects. However, there were a number of differences in sleep measures between the four conditions tested. Of these, possibly the most important were reduced sleep latencies and latencies to stage 4 sleep (deep sleep) which were associated with increased numbers of aircraft noise events in the evening shoulder hours, and increased REM sleep in the early morning associated with increased numbers of aircraft noise events in the early morning shoulder hours, together with changes in the frequency content of the EEG associated with each of the noise conditions. There were no differences in sleep measured using actigraphy, although it is unlikely that any differences could have been detected by this technique with the small numbers of subjects tested.

4.4 - Summary of findings

The overall incidence of sleep disturbance observed in the field was generally low and broadly consistent with the 1992 UK Field Study. There were no major differences in sleep measures between the 'high noise' and 'lower noise' areas although there were some effects of the number of aircraft noise events occurring during the 'lights out' periods. It should be noted that the 1999 UK Trial Methodology Study was not large enough to obtain statistically definitive results. In addition, there were no significant differences in indoor noise levels between the 'high noise' and 'lower noise' areas.

Because of the focus on trial methodology, the 1999 laboratory results must also be considered indicative rather than definitive. The three most interesting findings from the laboratory study were: the laboratory and field study data were generally comparable for many of the variables investigated; the numbers of reported awakenings (without any corresponding increase in actual awakenings) and REM sleep durations were associated with increased numbers of aircraft noise events in the early morning shoulder hours; and some sleep latencies were negatively associated with increased numbers of aircraft noise events in the evening shoulder hours. These findings imply that data from laboratory studies can be related to the field situation, a factor that has not been apparent in previous attempts to link field and laboratory findings. Individuals may have some awareness, in terms of next day subjective reports, of aircraft noise events occurring while they are asleep and increased numbers of aircraft noise events in the evening shoulder hours may help individuals to get to sleep quicker. However, the possible soporific effect of aircraft noise should be viewed with caution. Some aspects of performance were impaired prior to retiring to bed, suggesting that some subjects may have been partially sleep deprived before these study nights and hence have a greater tendency to enter the deeper stages of sleep quickly. There was no evidence of delayed sleep onset or premature awakening caused by shoulder hours aircraft noise events.

5 - RECOMMENDATIONS

The differences observed in the laboratory study between the four aircraft noise event conditions tested and the general comparability of the laboratory and field data have demonstrated that it is feasible to 'extend' the 1992 UK Field Study to the shoulder hours (research option A) by using the combined laboratory and field study methodology.

Research option B (compare 'high noise' and 'low noise' communities) could also be followed up by using the combined laboratory and field study methodology, particularly because it is difficult to control indoor aircraft noise exposure in the field within desired experimental parameters. The possibility of identifying some overall measure of sleep quality or sleep loss that could be related to objectively measurable next day effects depends on finding significant differences in those effects. To obtain differences in next

day effects which might be considered as precursors of longer term health effects would probably require much larger differences in indoor aircraft noise exposure than were observed in this study. An alternative approach would be to compare individuals living in areas with high aircraft noise with those living where there is no aircraft noise, matching for other factors within each group. A further potentially promising alternative could be to determine the aircraft noise event parameters that produce effects on next day performance; such effects could be related to efficiency and performance at work, which in turn could have long term economic impacts.
Research option C could be followed up by comparing self-reported noise sensitive and noise insensitive people under controlled laboratory test conditions as well as in their own homes where indoor aircraft noise exposure cannot be controlled.

REFERENCES

1. **J B Ollerhead at al.**, *Report of a field study of aircraft noise and sleep disturbance*, Dept of Transport, 1992

2. **B Berglund and T Lindvall**, *Community Noise*, Archives of the Center for Sensory Research, 1995