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

I-INCE Classification: 6.6

MULTILEVEL DISCRETE TIME HAZARDS MODELS OF SLEEP DISTURBANCE DUE TO AIRCRAFT NOISE AT NIGHT

I. Diamond*, L. Reyner, J. Horne**, V. Brooks*****

* U. Southampton, The University, SO17 1BJ, Southampton, United Kingdom

** Loughborough University, The University, LE11 3TU, Loughborough, United Kingdom

*** NATS, 39 Kingsway, WC2, London, United Kingdom

Tel.: 44 1703 592518 / Fax: 44 1703 593846 / Email: idd@socsci.soton.ac.uk

Keywords:
SLEEP DISTURBANCE, MULTILEVEL MODELLING, AIRCRAFT NOISE, ACTIMETRY

ABSTRACT
A major study of sleep disturbance due to aircraft noise at night was conducted in 1991 in the UK and a report published in 1992. The study used actimetry and measured, on 400 subjects at eight sites around four airports, whether or not an individual was disturbed in each 30 second epoch across 14 nights. This paper extends earlier work on random effects model to develop a multilevel model of disturbance.

1 - INTRODUCTION

A major study of aircraft noise and sleep disturbance was published in December 1992. A sample of 400 people at eight sites, two sites at each of Manchester, Gatwick, Heathrow, and Stansted, had their sleep monitored over a period on nights. Sleep disturbance was measured at 30 second intervals (called epochs) from the onset of sleep through-out the night. These time intervals were then matched to the known aircraft noise events (ANEs) and measures of the external noise caused by the aircraft were taken. The basic data consist of information on 84,989 epochs of sleep that contained an ANE. (The models are based on 84.952 observations due to a small number of cases with missing data for the noise level.) This is restricted to those people who fall asleep after 11:00 pm. Only a slight restriction that allows us to study patterns as the night progresses without the problem of including a few people who started sleep much earlier and who would have been subjected to many ANEs before the night flying regulations start. The data also includes a summary of the arousal's during the 'quiet' epochs of sleep. This is important as it allows us to control for the underlying probability of waking.
Using the data arousal rates (or the probability of waking) can be calculated that do not account for the characteristics of the individuals or the fact that the epochs are repeated observations within nights of study within individuals and can therefore not be treated as an independent sample. Table 1 gives a summary of these results.

Site		All Epochs	'Quiet' Epochs	ANE Epochs
TOTAL	Arousal Rate	5.27	5.25	6.10
	(%)	"0.02	"0.02	"0.16
	95% CI (%)	4,286,520	4,201,531	84,989
	N			

Table 1: Overall arousal rates across epochs by site and occurrence of an ANE.

Clearly, the data cannot be seen as a set of independent observations. They are repeated observations by night within subject. Multilevel modelling is a framework that allows us to include this clustering and get a measure of the effect due to variability from night to night within subjects as well as an effect

due to the variability between subjects that is not picked-up by the explanatory variables in the models. Therefore, in each case a three level model has been used; ANE epoch within night within subject.
The model can be written as

$$\text{logit}\pi_{ijk} = \alpha \ + \beta^1 X_{ijk} + \gamma_{jk} + V_k$$

where π_{ijk} is the probability of being disturbed in epoch i on night j for subject k, α and β are estimated regression coefficients, X is a matrix of covariates, γ_{jk} and V_k are the second and third level variances respectively.
The model is fitted using penalised quasi likelihood estimation.
The main part of the analysis is an all site model from 11:00 pm to 7:00 am. This utilises all the data from all the sites.

2 - ALL SITE MODEL RESULTS

The results for the variables included in the 'final' model are presented in Table 2.
Table 2 also presents the random effects, which are significant at both the night and subject level. The subject level random effect confirms that there is a considerable amount of between subject variability that is unmeasured. The night within subject variability is slightly surprising considering that the subjects underlying arousibility for the night is controlled for in the model. Its existence perhaps confirms that the sleep process on any particular night is very complex and on some nights people are more susceptible to ANEs than other nights regardless of the underlying arousibility.
Perhaps the best way to see some of these results is using a graph. In Figure 1 the red dotted lines represent 95 percent prediction intervals around the mean predicted probability of waking during an ANE epoch, the random effects are set at zero. Figure 2 presents the same information but by 'Sleep Time' rather than the noise level. Figure 3 combines the 2 random effects. Outside the two lines is the probability of extreme subjects experiencing extreme nights (around 1 per 1,000 people per night.

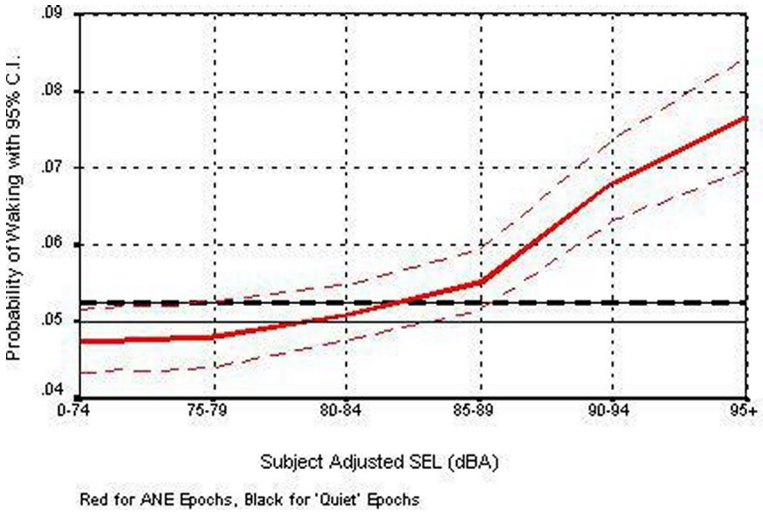

Figure 1: Arousal rates for the all site model by ANE noise level.

Variable	Parameter (SE)	Odds Ratio	95% CI for Odds Ratio
Constant	-3.572 (0.133)	-	
Site			
Heathrow (HLW)	Base Category	1	-
Gatwick (LGN)	(0.094)	1.32	1.10 to 1.59
Heathrow (SWM)	0.140 (0.116)	1.15	0.92 to 1.44
Gatwick (LFD)	(0.088)	1.19	1.00 to 1.41
Manchester (HGN)	(0.081)	1.32	1.12 to 1.54
Manchester (EDG)	(0.089)	1.21	1.01 to 1.44
Stansted (HAT)	(0.129)	1.11	0.86 to 1.42
Stansted (WSB)	0.049 (0.147)	1.05	0.79 to 1.40
Noise Level (dBA)			
0-74	Base Category	1	-
75-79	0.017 (0.058)	1.02	0.91 to 1.14
80-84	0.079 (0.055)	1.08	0.97 to 1.21
85-89	0.163 (0.055)	1.18	1.06 to 1.31
90-94	0.388 (0.058)	1.47	1.32 to 1.65
95+	0.515 (0.066)	1.67	1.47 to 1.91
Quiet Arousal Rate			
0.00 # r $<$ 0.04	Base Category	1	-
0.04 # r $<$ 0.06	0.211 (0.047)	1.23	1.13 to 1.35
0.06 # r $<$ 0.08	0.417 (0.054)	1.52	1.36 to 1.69
0.08 # r $<$0.10	0.577 (0.074)	1.78	1.54 to 2.06
0.10 # r	0.743 (0.134)	2.10	1.62 to 2.73
Time Since Last ANE (Epochs)			
0-4	Base Category	1	-
5-9	0.025 (0.050)	1.03	0.93 to 1.13
10-14	-0.007 (0.060)	0.99	0.88 to 1.12
15-19	0.056 (0.066)	1.06	0.93 to 1.20
20-24	0.063 (0.074)	1.07	0.92 to 1.23
25-29	0.129 (0.079)	1.14	0.97 to 1.33
30-44	0.179 (0.061)	1.20	1.06 to 1.35
45-59	0.125 (0.080)	1.13	0.97 to 1.33
60-89	0.099 (0.079)	1.10	0.95 to 1.30
90+	0.218 (0.064)	1.24	1.10 to 1.41
Before Sleep	-0.160 (0.110)	0.85	0.69 to 1.06
Missing	0.264 (0.117)	1.30	1.04 to 1.64
Window State			
Open	Base Category	1	-
Single-Glazed Closed	-0.031 (0.047)	0.97	0.88 to 1.06
Double-Glazed Closed	-0.125 (0.059)	0.88	0.79 to 0.99
Missing	0.167 (0.109)	1.18	0.95 to 1.46
Age (years)			
20-34	Base Category	1	-
35-49	-0.091 (0.051)	0.91	0.83 to 1.01
50-70	-0.141 (0.055)	0.87	0.78 to 0.97
Sex			
Females	Base Category	1	-
Males	-0.145 (0.044)	0.87	0.79 to 0.94
Random Effects			
Subject Level	0.058 (0.011)	1	0.62 to 1.62
Night Level	0.055 (0.018)	1	0.63 to 1.60

Table 2: All site model parameters and odds ratios.

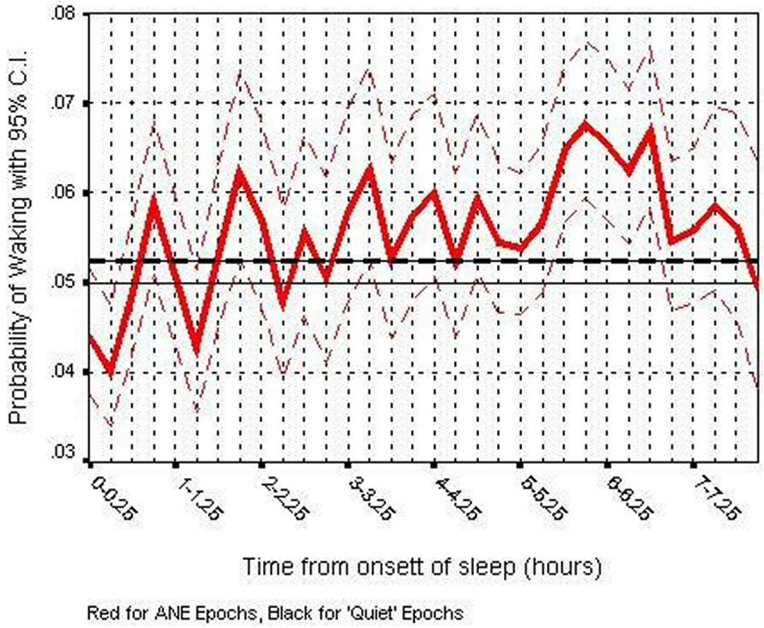

Figure 2: Arousal rates for the all site model by sleep time.

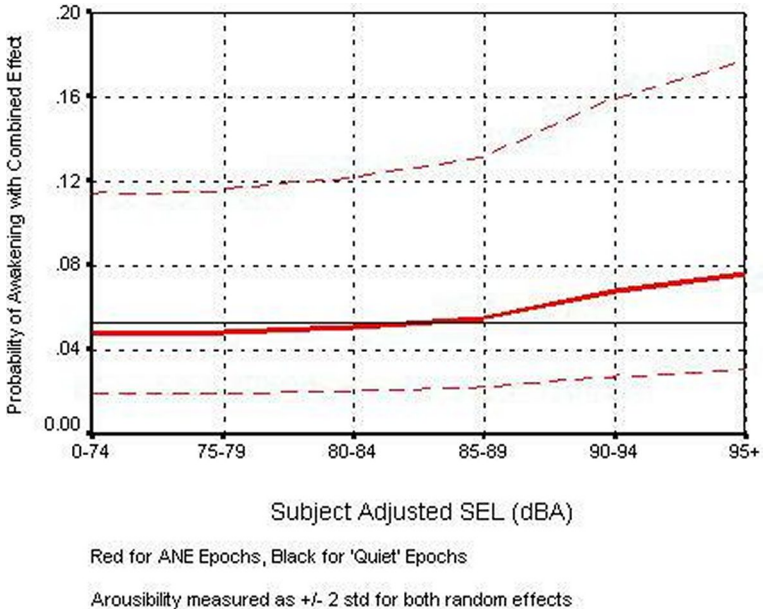

Figure 3: The combined effect of subject and night variability.

REFERENCES

1. **Ollerhead et al**, *Report on a field study of aircraft noise and sleep disturbance*, Department of Transport, 1992