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# SUMMARY OF FINDINGS OF RECENT FIELD STUDIES OF NOISE-INDUCED SLEEP DISTURBANCE IN THE UNITED STATES

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**ABSTRACT**
Field studies of similar design of the ability of aircraft noise to disturb sleep have been completed within the last several years near five airfields in the United States. These have included large military and civil airfields, as well as a general aviation airport. The results of these studies indicate that relatively few nighttime noise intrusions disturb sleep, and that residential populations near airports are either self-selected or adapted to such nighttime noise. Non-acoustic factors (such as the meaning of nocturnal noise intrusions) may well account for much of the ability of sounds to awaken people sleeping in familiar quarters.

## 1 - INTRODUCTION

The findings of 21 studies of the effects of noise on sleep were reanalyzed in an effort to develop a quantitative dosage-response relationship (Pearsons, Barber, Tabachnick, and Fidell, 1995). Large and systematic differences in sleep disturbance were observed between the findings of studies conducted in laboratory and in field settings. Recent field studies have provided additional evidence of the association between behavioral awakening and aircraft noise, including Fidell, Pearsons, Tabachnick, and Howe (2000); Fidell, Howe, Tabachnick, Pearsons, Silvati, Sneddon, and Fletcher (1998); Fidell, Pearsons, Tabachnick, Howe, Silvati, and Barber (1995a); and Fidell, Howe, Tabachnick, Pearsons, and Sneddon (1995b). These studies have been conducted in the vicinity of large civil airports at Los Angeles, California and Denver, Colorado; near a military airbase with large jet aircraft (B 52's); and near a large general aviation airport used by a range of turbofan and turboprop aircraft near Atlanta, Georgia. These studies have all used behavioral awakening as an indication of sleep disturbance, and measured nighttime noise events in test participants= bedrooms. Indoor sound exposure levels (SEL) were used as predictors of sleep disturbance.

## 2 - BACKGROUND

A primary reason for conducting these U.S. studies was to study the effects of adaptation to see whether familiarity with intruding sounds could explain the large differences in sleep disturbance noted in field and laboratory environments. The opening of a new airport and closing of an old one in Denver, Colorado provided a unique opportunity to investigate sleep disturbance in an area near the old airport (Stapleton International Airport) where people had been exposed for years to aircraft noise and would, after its closure, be free from the noise of nighttime aircraft operations. The opening of a new airport in Denver (Denver International Airport) provided a unique opportunity to investigate sleep disturbance in an area near the new airport where people had not been exposed to aircraft noise and would, after the opening, be suddenly exposed to the noise of nighttime aircraft operations.
Surprisingly, gross numbers of awakenings per night were not strongly related to the changes in aircraft operations following the closure of the old airport and the opening of the new airport, neither for those

study participants who were relieved of long-term exposure to aircraft noise, nor those participants who were suddenly exposed to novel aircraft noise. The findings of the Denver studies were consistent with the information previously analyzed by Pearsons *et al.* (1995) and fully supported the dose-response relationship observed for previous field studies.

A further attempt was made to study habituation at DeKalb-Peachtree Airport, a large general aviation airport near Atlanta, Georgia, that expected increased nighttime flight operations due to the Olympic Games in July and August of 1996. Again, as in the previous study near Denver, no effect of adaptation was noted.

Additional measures of sleep disturbance (principally motility) were also made in some of the recent U.S. studies. These motility measurements were collected by means of actigraphs or actimeters worn on the wrist to monitor movement throughout the night. Results of these measurements (percent movements during noise events) were subsequently converted to estimates of percent awakenings associated with noise events.

**3 - RESULTS**

The results for the studies using direct measures of behavioral awakening are shown in Figure 1. This figure contains the recent studies noted above and some earlier field studies conducted during the period from 1980-1995 in the U.S. and Europe. Also shown in this figure are the 95 percent confidence interval limits. The relationship including the confidence limits are currently part of the pending standard in the U.S. for estimating sleep awakening from aircraft noise.

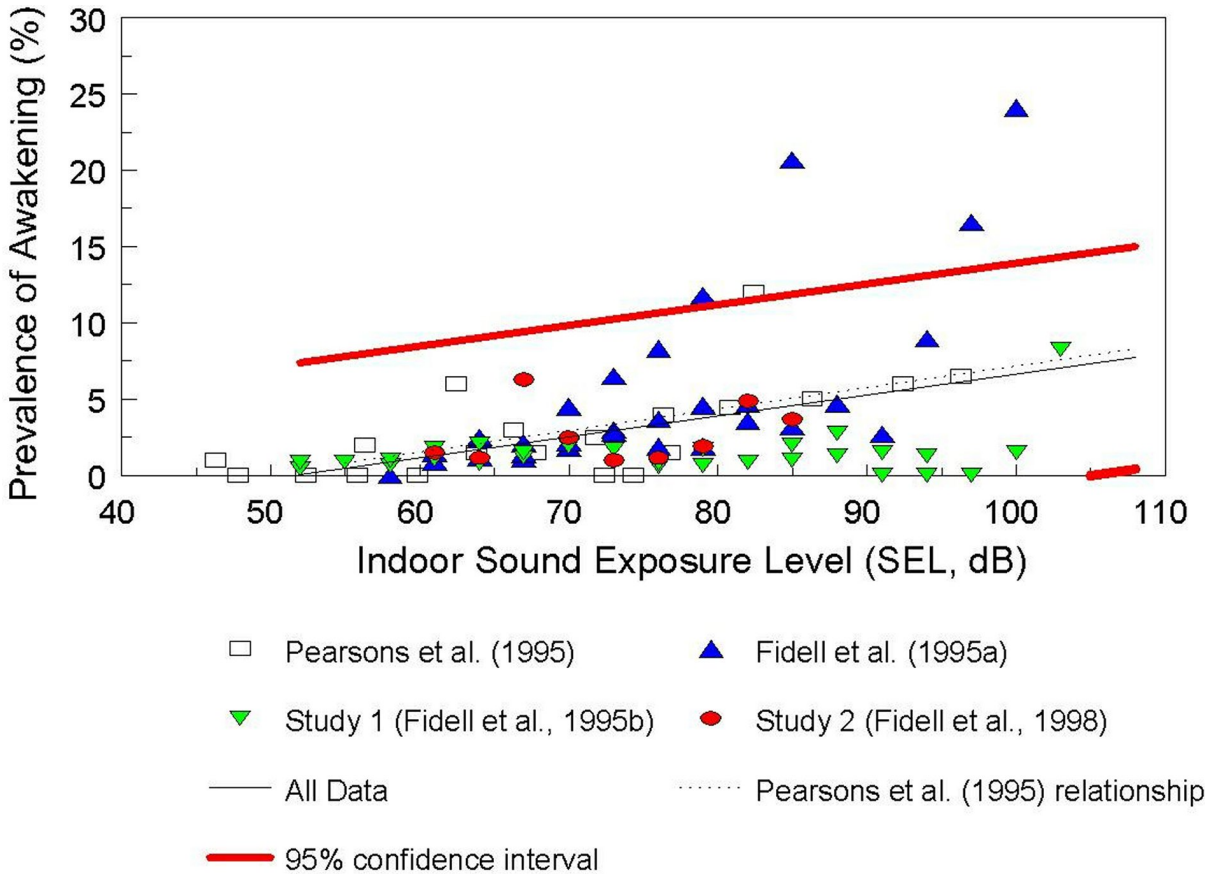


**Figure 1:** Summary of awakening data as measured directly in field experiments.

Additional information providing some support to this standard is available from the motility data gathered during some of the U.S. studies and a major study conducted in the U.K. (Ollerhead, J. B., Jones, C. J., Cadoux, R. E., Woodley, A., Atkinson, B. J., Horne, J. A., Pankhurst, F., Reyner, L., Hume, K. I., Van, F., Watson, A., Diamond, I. D., Egger, P., Holmes, D. and McKean, J.,1992). Figure 2 includes the results of the studies using motility as an estimate of behavioral awakening. The agreement between direct and estimated (from motility data) behavioral awakening is encouraging. However, it is important that future tests on sleep disturbance include motility measurements in conjunction with

behavioral awakening in order to Acalibrate@ the motility data.

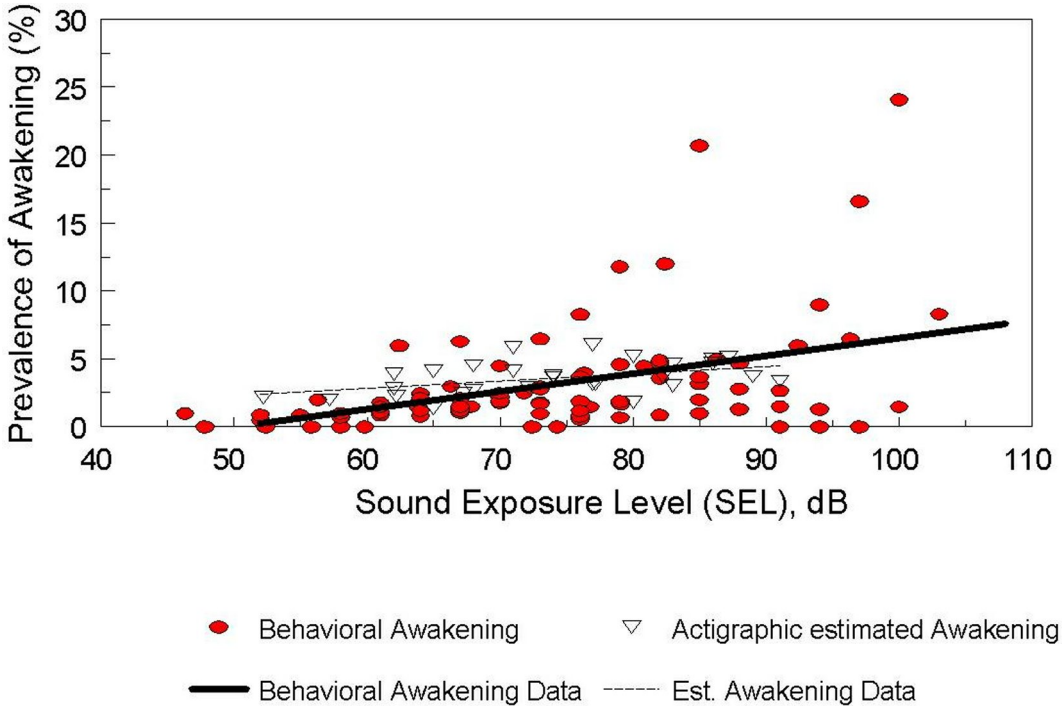


**Figure 2:** Summary of awakening data as measured directly in field experiments and estimated from motility data.

The body of information now available on noise-induced sleep disturbance (approximately 11,000 subject-nights) suggests that additional research of the same nature is unlikely to lead to new findings. Several concerns regarding noise-induced sleep disturbance remain, however. These include

- Large variability in the results
- Differences in results between laboratory and field studies
- Applicability of the research to noise sources other than aircraft
- Lack of long-term studies
- Sensitive groups
- The effect of meaning of sound

## 4 - CONCERNS ABOUT PRESENT SLEEP AWAKENING DATA

The large variability in results is apparent in the summaries shown in Figures 1 and 2. At 85 dB SEL the average percent awakening from aircraft noise is 7%. Including the calculated 95% confidence interval doubles the percent awakenings to 14%. Some data points in the figures indicate percentages of awakening as high as 20% at noise levels of 85 dB SEL. Moreover, data from the figures show that some people are not awakened at all at these SEL values.

Figure 3 shows results of sleep disturbance studies conducted in laboratory settings. In a laboratory environment, 40% of the subjects wake up at an SEL of 85 dB, although some data points suggest that the percent awakenings can be as high as 75% at the same SEL value. Certainly factors other than the noise level of the intruding sound are playing a role in the wake-up process.

Taking the relationship for field data of percent awakened for various awakenings shown in Figure 1 and applying it to the level produced by an alarm clock that lies in the range of SEL=s from 80-90 dB suggests that only 6% of the population would awaken. If acoustic factors alone accounted for awakenings, alarm clocks would be of little value.

Anecdotal evidence has long pointed out the importance of the meaning of sounds in awakening. The cry of a baby, the click of a door latch, and a footfall in a bedroom at night, are all capable of awakening,

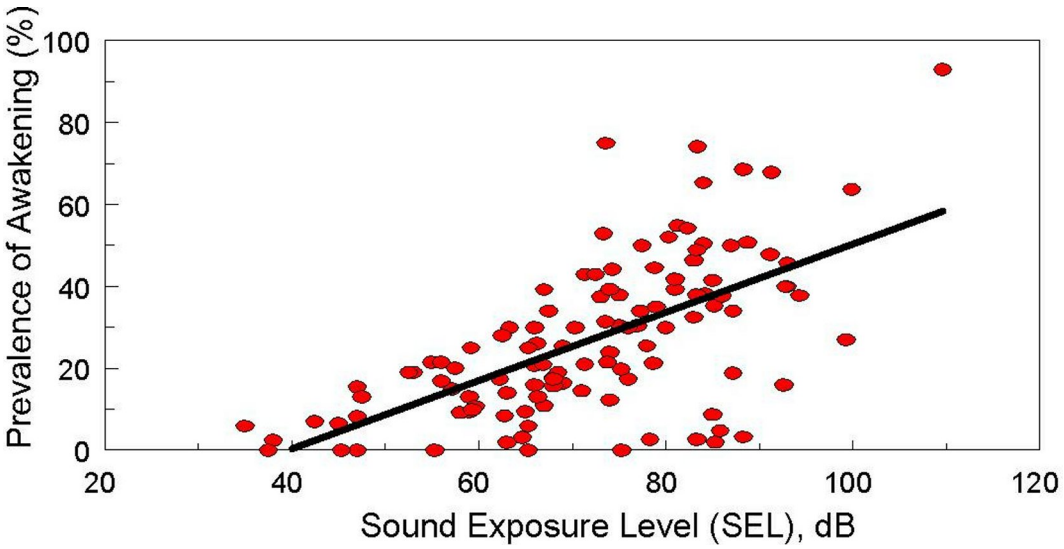


**Figure 3:** Summary of awakening data as measured directly in laboratory experiments.

even at levels well below the range of aircraft noise shown in Figure 1 that at most is associated with awakening of only 25% of the people. The present data are further limited in their application to sources of noise other than aircraft. If meaning plays a role in the waking potential of sounds, then other sound sources such as road traffic, railways, industrial and people may generate quite different relationships than that shown in Figures 1 and 2.

All of the sleep studies summarized here have used normal, healthy participants and have not attempted to take into consideration other, possibly more sensitive people such as found in hospitals, night shift workers, children or the elderly.

Perhaps the greatest limitation of all of the sleep studies is the lack of evidence concerning the health effects of awakenings. Are the health consequences of four awakenings per night significantly different than those of two awakenings per night? The answers to such questions remain elusive.

## 5 - RECOMMENDATIONS

The limitations of the current data on sleep disturbance suggest the need for further research. The studies should include some effort in determining the effects of the meaning of sounds, perhaps even including unfamiliar sounds in unfamiliar environments. Instructions should be varied and incentives added or subtracted to test the effect of motivation on awakening. The metrics of sleep disturbance and noise levels that have been used in the recent tests should be preserved for the sake of consistency of analysis to include motility (actimetry), behavioral awakening, and EEG.

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