National Sleep Study on the Effects of Aircraft Noise on Sleep: Results of two Pilot Field Studies

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Introduction

• Field studies are needed to acquire current US data on sleep disturbance relative to varying degrees of aircraft noise exposure to inform any potential policy considerations.

• An inexpensive methodology of using actigraphy and electrocardiography (ECG) has previously been found to provide a sensitive measure of awakenings.

• We established the feasibility of having study participants complete unattended ECG and actigraphy measurements in a 3 night study near Philadelphia Airport.

• Based on lessons learned from the Philadelphia study, the methodology was further refined and tested near Atlanta Airport.
Objectives

• Determine feasibility of a completely unattended field study in which
  – Equipment is sent to participants with detailed instructions
  – Participants apply electrodes themselves and start and stop measurements for 5 consecutive nights
  – Participants take down and send back equipment

• Determine best approach for participant recruitment via postal surveys
Survey Main Purposes

– Recruitment of Field Study Subjects (Primary Purpose)
  • Several questions addressed eligibility criteria

– Non-response Analysis
  • Are those participating in the field study representative of those in the sampling universe or those who responded?
  • This comparison can potentially inform weights used for adjusting for non-response bias.

– Investigation of Aircraft Noise Effects on Selected Outcomes, for Example
  • Self-reported sleep disturbance
  • Self-reported health outcomes
Recruitment Survey

– Brief surveys were mailed to randomly selected households in 10 sampling regions:
  • Five sampling regions each East and West of the airport
  • Noise categories: $L_{\text{night}} < 40$ dB (control region), 40-45 dB, 45-50 dB, 50-55 dB, and $> 55$ dB

– The survey contained sleep, health, and demographic questions.

– Participants indicated whether they would like to take part in the home sleep study on the survey.

– The survey could be returned using a prepaid envelope or completed online.
Recruitment Survey

17 mailing waves (each wave consisted of 240 addresses – 4,080 addresses total)

- **Incentive for returning the survey**
  - Promised $2, $5, or $10 Amazon gift card (waves 1-5)
  - Pre-paid $2 cash (waves 6-17)

- **Survey length**
  - Long (waves 1-7, 10-17)
  - Medium (contains all eligibility questions, wave 8)
  - Short (additional telephone screening necessary, wave 9)

- **Subject compensation for field study**
  - $100 (waves 1-5)
  - $150 (waves 6-9)
  - $200 (waves 10-17)

- **Survey follow-up**
  - No follow-up (waves 1-4, 11)
  - Pre-notification postcard (wave 5)
  - 3-wave follow-up (waves 6-10, 12-13)
  - 2-wave follow-up (waves 14-17)

We received 407 surveys.
Optimal Recruitment

Survey Incentive
- Gift card (ref)
- $2 cash

Survey Length
- Short (ref)
- Medium
- Long

Follow-up Waves
- 0 (ref)
- 2
- 3

Field Study Participation Amount
- $150 (ref)
- $200

Survey completion
Interest in field study
Participation in field study

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## Optimal Recruitment

<table>
<thead>
<tr>
<th>Sampling protocol</th>
<th>Surveys sent to receive 1 response (n)*</th>
<th>Surveys sent to recruit 1 participant (n)*#</th>
<th>Initial wave</th>
<th>Follow-up wave 1</th>
<th>Follow-up wave 2</th>
<th>Follow-up wave 3</th>
<th>Total per mailed individual</th>
<th>Per response received*</th>
<th>Total to receive 1 response†</th>
<th>Recruit 1 participant†#</th>
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<tbody>
<tr>
<td>Follow-up waves (n)</td>
<td>Survey length</td>
<td>Survey incentive</td>
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<td>4.9</td>
<td>53.6</td>
<td>3.09</td>
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<td>1.09</td>
<td>1.09</td>
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<td>12.2</td>
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<td>-</td>
<td>-</td>
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<td>5.96</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>1.09</td>
<td>40.83‡</td>
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</table>

Based on models adjusted for number of follow-up waves, survey length, survey incentive

*Assumes 100% delivery rate
†Assumes 87.6% delivery rate and, if applicable, $0.248 recouped from non-deliverable surveys
‡Includes a mean gift card cost of $5.67
#Assumes 9.1% participation rate from completed surveys across all survey mailing rounds, independent of mailing protocol.

Does not include cost for actual participation in the field study ($150 or $200).
Approach-In Home Study

- Equipment is mailed to participant’s homes
- An instruction manual and videos are provided on how to use the equipment
- Physiological Monitoring: 2 cable (1 channel) ECG (1 kHz) and body movements (10 Hz)
- Sound recording equipment: Portable audio recorder with class 1 microphone
- Total equipment cost for 1 setup ~$1500
- Participants take part for 5 consecutive nights
- Staff are available 24/7 by cell-phone to answer questions
Approach—In Home Study
Heart Rate Splitter

Software Development

Arousal Determination

Respiratory Movement Visualization

MP3 Conversion

Time Drift Correction

Noise Event Classification

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Event-related Analysis

- 37 subjects consented to participate in the study
- 3 subject consented but did not participate in the measurements (1 did not return the equipment)
- In 9 subjects the acoustical calibration before the equipment was sent out and after it was returned differed by >2 dBA and was considered invalid
- Of the remaining 25 subjects 3 subjects were excluded because:
  - Only 1 aircraft noise event was recorded in 1 valid night
  - No aircraft noise event was recorded in 4 valid nights
  - No acoustic data were recorded
- Therefore, 22 subjects (8 male; mean ± SD age 50.0 ± 14.0 years; mean ± SD BMI 27.8 ± 3.3 kgm⁻²) contributed to the final analysis.
We experienced no more data loss after the gain wheel was fixed.
Event-related Analysis

– A 50 second noise window (starting 5 s before the marked start of an aircraft event) was screened for an awakening.

– A total of 1,667 aircraft noise events contributed to the data analysis.

– Non-linear mixed effect models were used for data analysis in SAS (Version 9.4) with awakenings determined by heart rate increases and body movements as the outcome of interest.

– For the exposure-response function, spontaneous awakenings were taken into account by subtracting awakening probability at 29 dB (median background noise level).
Event-related Analysis

The average $L_{AS,max}$ of aircraft events was 40.1 dB (median 39.4 dB, range 28.9 dB-63.4 dB). Average noise levels in the minute preceding the start of each aircraft noise event were 30.9 dB (median 29.8 dB, range 22.4 dB-56.5 dB).
Event-related Analysis

Number of aircraft noise events per subject for each of the 5 study nights. The colors indicate study nights.
## Event-related Analysis

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th></th>
<th></th>
<th>Model 2</th>
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<td></td>
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<td>SE</td>
<td>p-value</td>
<td>Estimate</td>
<td>SE</td>
<td>p-value</td>
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<td>$L_{A_{S\text{max}}}$ [dB]</td>
<td>0.0288</td>
<td>0.0148</td>
<td>0.0647</td>
<td>0.0254</td>
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<td>0.0005</td>
<td>0.3346</td>
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</table>

SE: Standard Error
Event-related Analysis

Dashed lines represent 95% confidence intervals.
Summary

• Lessons learned
  – The recruitment process was optimized to maximize response rate at minimal cost.
  – Those who participated in the field study were in many, but not all, ways similar to those who returned the survey but were not eligible or did not want to participate in the field study (data not shown).
  – We identified ways to minimize data loss during the field study.
  – Overall, the approach was found to be feasible.

• Next steps
  – Perform a U.S. national study on the effects of aircraft noise on sleep.
  – Based on power calculations, we will investigate 400 subjects at 77 U.S. airports over a period of 2 consecutive years.
Literature

• Basner M, Witte M, McGuire S
"Aircraft Noise Effects on Sleep—Results of a Pilot Study Near Philadelphia International Airport."

• Smith MG, Witte M, Rocha S, Basner M
"Effectiveness of incentives and follow-up on increasing survey response rates and participation in field studies."

• Rocha S, Smith MG, Witte M, Basner M
"Survey Results of a Pilot Sleep Study Near Atlanta International Airport."

• Smith MG, Rocha S, Witte M, Basner M
"On the feasibility of measuring physiologic and self-reported sleep disturbance by aircraft noise on a national scale: A pilot study around Atlanta airport."
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