FAA CENTER OF EXCELLENCE FOR ALTERNATIVE JET FUELS & ENVIRONMENT

Pilot Study on Aircraft Noise and Sleep

Project 17

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Alexandria, VA

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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

Schedule and Status

Period	Tasks
10/2015-9/2016	**Study Preparation:**
	• Design recruitment questionnaire
	• Develop study protocol and obtain Institutional Review Board (IRB) approval
	• Determine airport and obtain flight operations, predict L_{night} levels and number of overflights, identify sampling regions based on predictions
9/2016-9/2018	**Data Acquisition and Data Analysis:**
	• Mail out recruitment questionnaires
	• Mail out equipment for in-home sleep study
	• Analyze survey data and acoustic and physiological data collected during in-home sleep study

Currently in no-cost extension

Final Report has been completed and is under FAA review

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_{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
- Primary purpose of the survey is to determine eligibility for an in-home sleep study
- Participants indicate 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

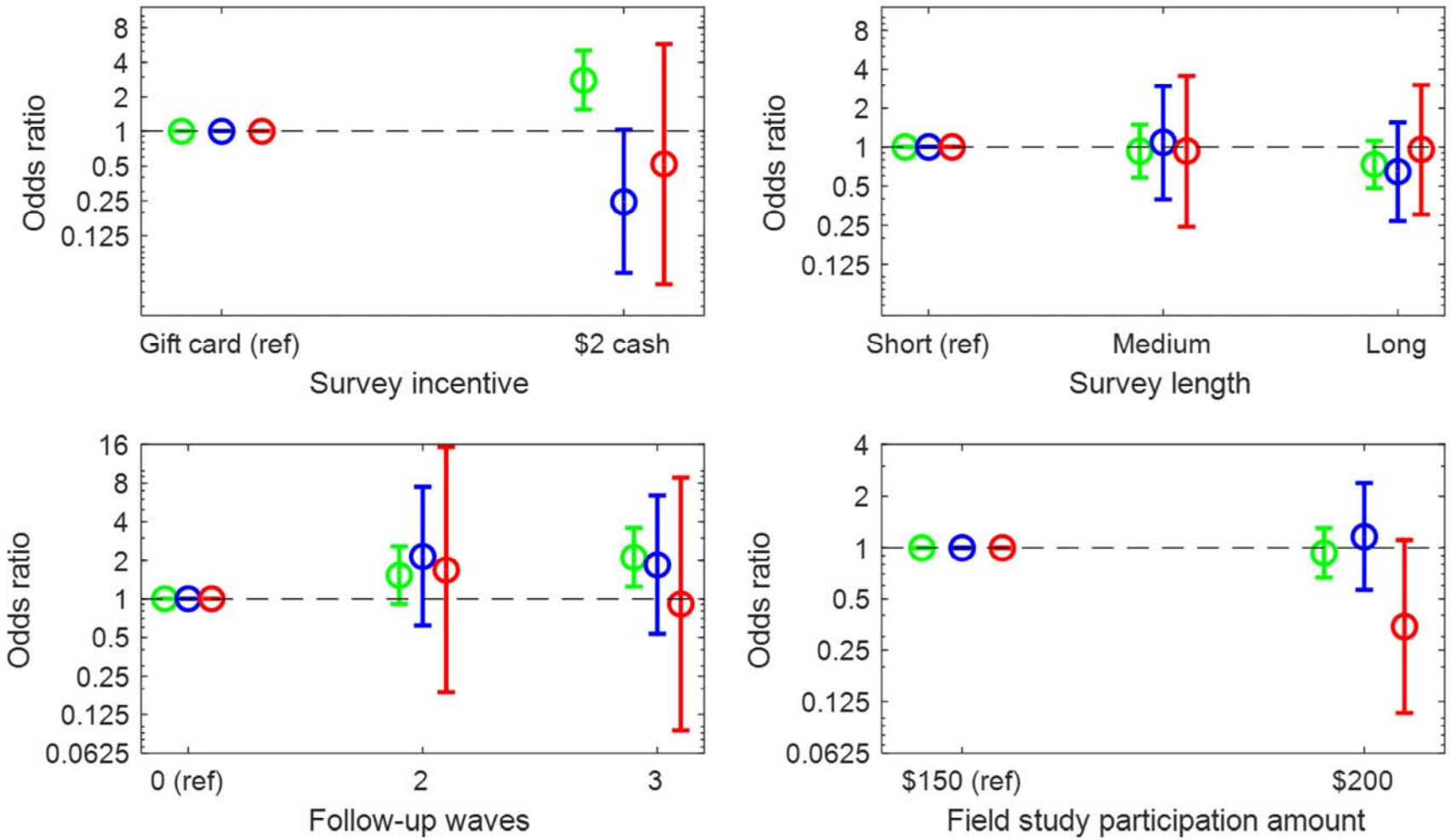
Recruitment Survey

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



Optimal Recruitment

Sampling protocol			Surveys sent to receive 1 response (n)*	Surveys sent to recruit 1 participant (n)*#	Costs ($)							
Follow-up waves (n)	Survey length	Survey incentive			Initial wave	Follow-up wave 1	Follow-up wave 2	Follow-up wave 3	Total per mailed individual	Per response received*	Total to receive 1 response†	Recruit 1 participant†#
3	Short	$2	4.6	50.7	3.01	0.70	1.01	1.01	5.74	26.44	28.89	317.51
3	Medium	$2	4.9	53.6	3.09	0.70	1.09	1.09	5.96	29.09	31.84	349.88
0	Long	$2	12.2	134.1	3.09	-	-	-	3.09	37.65	39.54	434.48
3	Long	$2	6.1	67.4	3.09	0.70	1.09	1.09	5.96	36.59	39.99	439.50
2	Long	$2	8.3	91.5	3.09	0.70	1.09	-	4.88	40.64	44.01	483.66
0	Long	Gift card	32.3	354.5	1.09	-	-	-	1.09	40.83‡	46.81‡	503.38

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

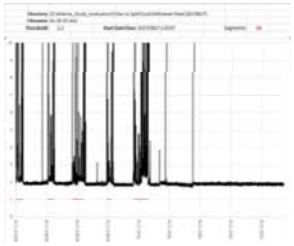
- Equipment is mailed to participant's homes
- An instruction manual and videos are provided on how to use the equipment
- Physiological Monitoring: 2 cable (1 channel) ECG (1 kHz) and body movements (10 Hz)
- Sound recording equipment: Portable audio recorder with class 1 microphone
- Total equipment 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

Software Development

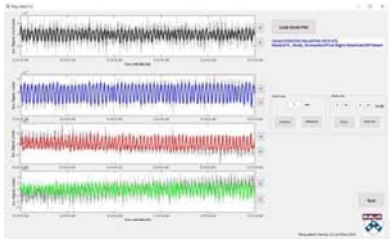
Arousal Determination

Heart Rate Splitter

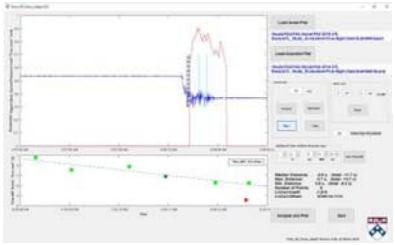


MP3 Conversion

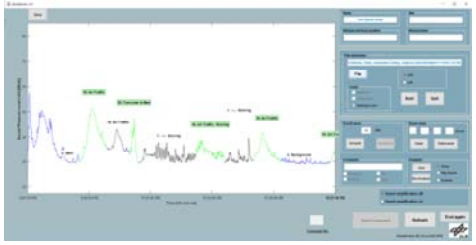
Respiratory Movement Visualization



Time Drift Correction



Noise Event Classification



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.**

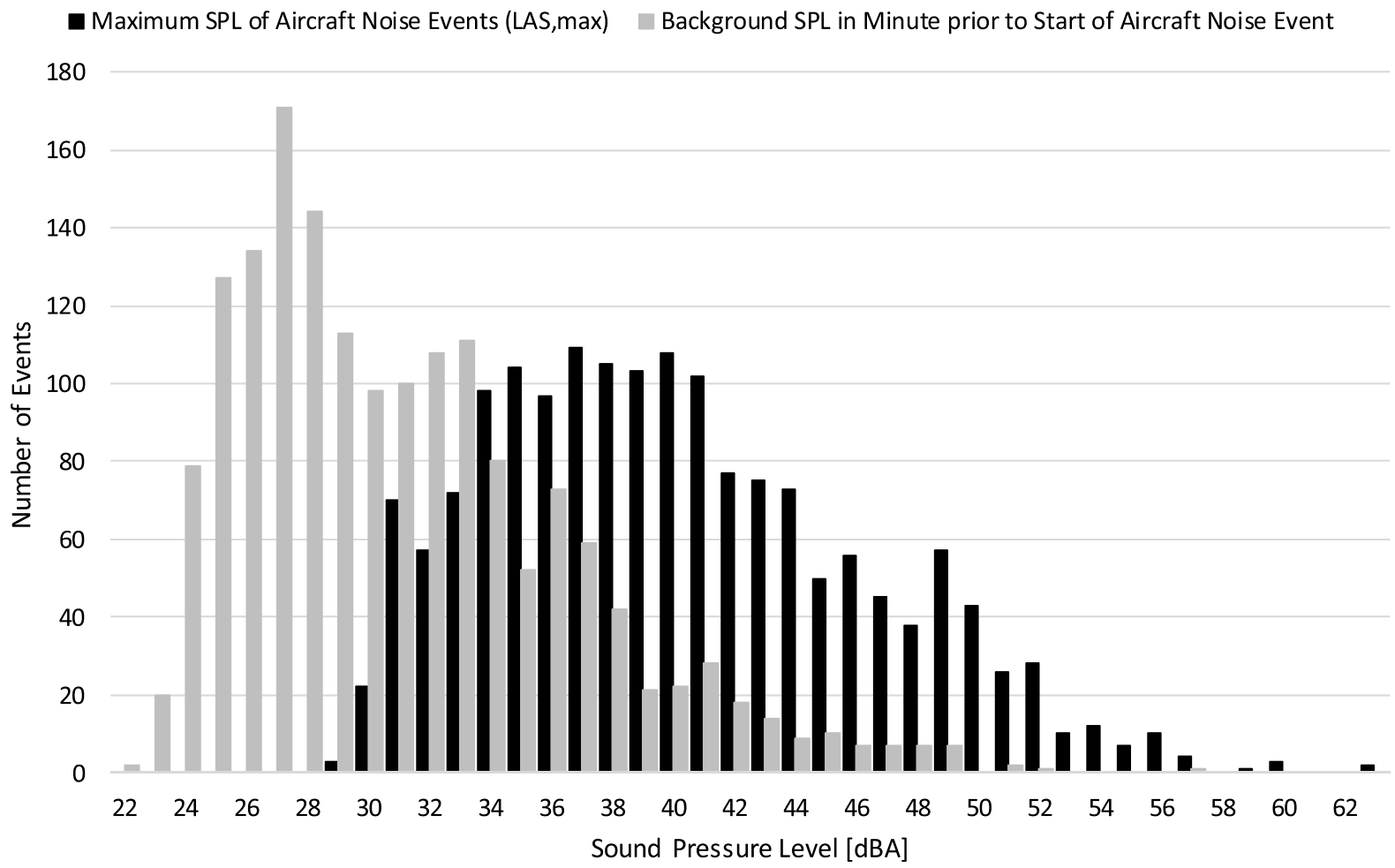
Sound Recorder Calibration

We experienced no more data loss after the gain wheel was fixed.

Event-related Analysis

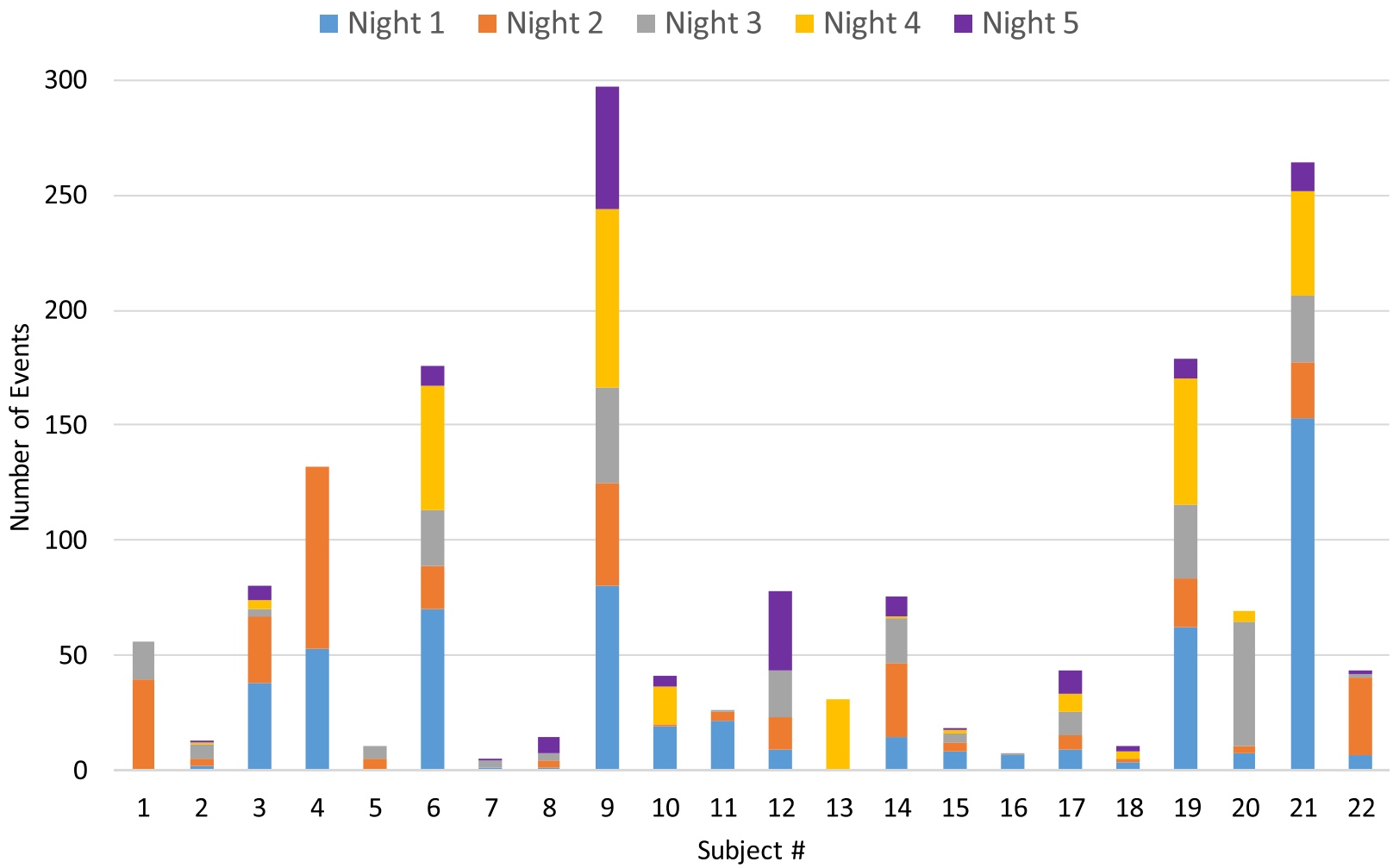
- A 50 second noise window (starting 5 s before the marked start of an aircraft event) was screened for an awakening.
- A total of 1,667 aircraft noise events contributed to the data analysis.
- Non-linear mixed effect models were used for data analysis in SAS (Version 9.4) with awakenings determined 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



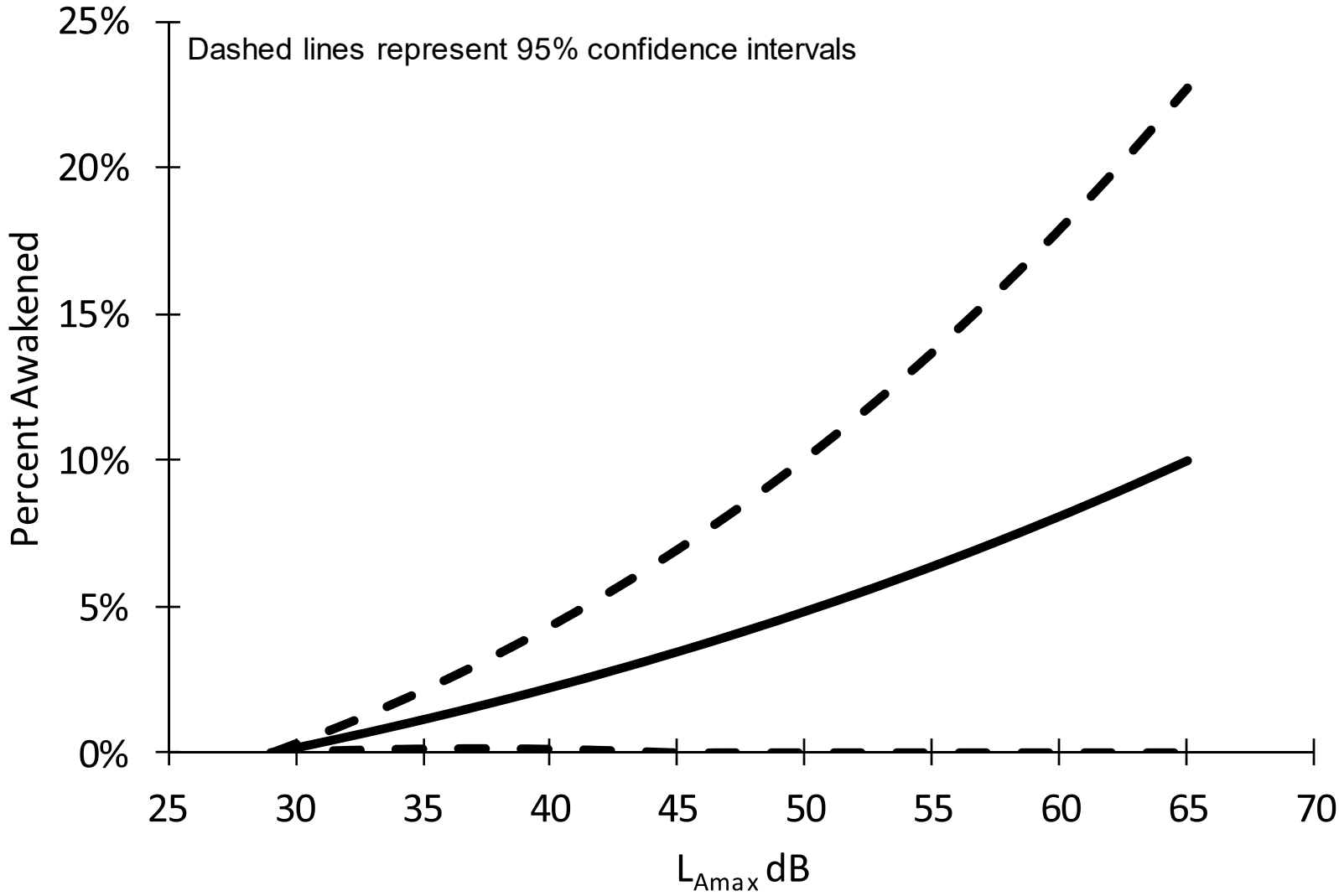
Number of aircraft noise events per subject for each of the 5 study nights. The colors indicate study nights.

Event-related Analysis

	Model 1			Model 2		
	Estimate	**SE**	**p-value**	**Estimate**	**SE**	**p-value**
L_{ASmax} **[dB]**	0.0288	0.0148	0.0647	0.0254	0.0126	0.0572
Age [years]				-0.0054	0.0052	0.3159
Male				-0.1359	0.2910	0.6454
BMI				-0.0021	0.0304	0.9450
Time [min]				-0.0005	0.0005	0.3346

SE: Standard Error

Event-related Analysis



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

Acknowledgements

- FAA has a cooperative agreement with DLR. The ECG and actigraphy methodology was jointly refined with colleagues from DLR.

Publications

- Basner, M., McGuire, S., Witte, M. Aircraft Noise Effects on Sleep—Results of a Pilot Study Near Philadelphia International Airport. International Journal of Environmental Research and Public Health, 16(17), 3178-96: 2019.
- Basner, M., Clark, C., Hansel, A., Hileman, J.I., Janssen, S.A., Shepherd, K., Sparrow, V.: Aviation noise impacts: state of the science. Noise & Health, 19(Mar-Apr), 41-50, 2017

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