Pilot Study on Aircraft Noise and Sleep

Project 17

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Motivation

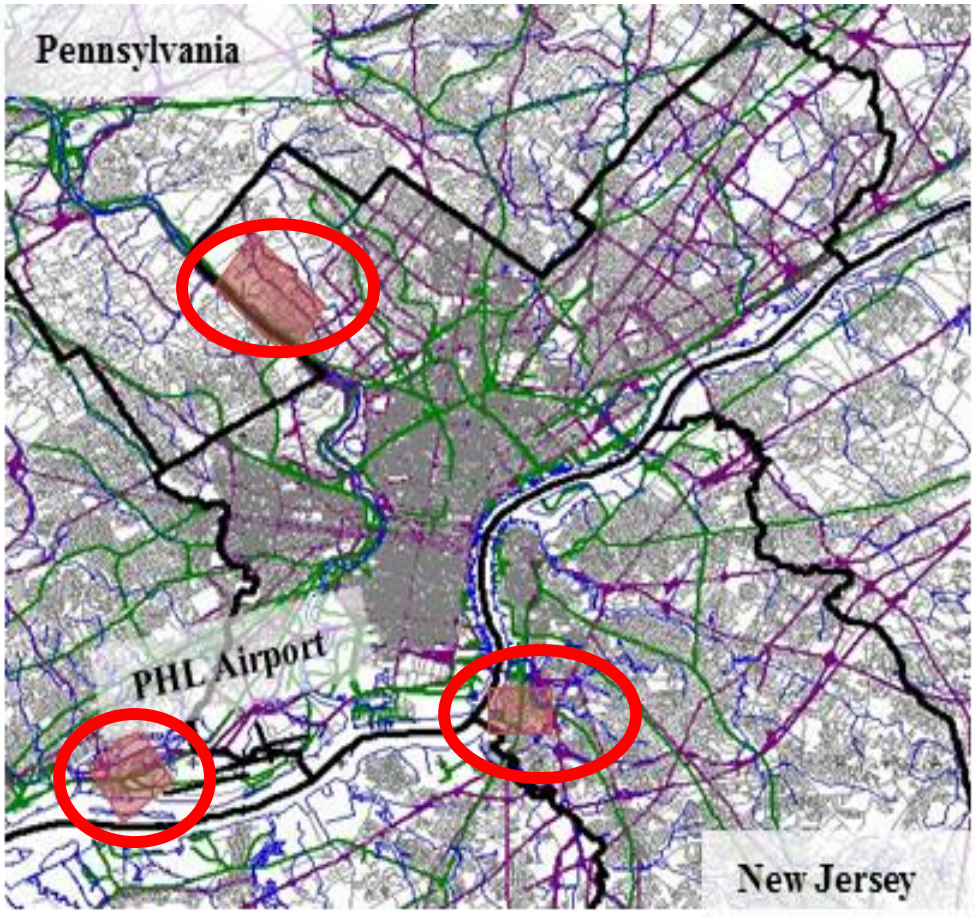
- Field studies need to be conducted in the US to acquire current data on sleep disturbance relative to varying degrees of noise exposure to inform policy
- A methodology of using actigraphy and electrocardiography (ECG) has previously been found to provide a sensitive measure of awakenings
- ECG + Actigraphy is non-invasive, self-administration of electrodes is possible, with lower methodological cost than polysomnography
- A pilot field study using this methodology was conducted near Philadelphia International Airport

Objectives

- Evaluate the completeness and quality of data obtained through unattended sleep measurements
- Compare sleep fragmentation, subjective sleep ratings, and subjective health ratings between individuals living near the airport and individuals without relevant amounts of air-traffic (control region)
- Develop models relating awakenings to indoor noise levels
- Further refine study protocol and methodology based on lessons learned for a potential future multi-airport study

Measurement Site Selection

- PHL airport was selected due to its proximity to the University of Pennsylvania and its relevant amount of nighttime operations
- 40 participants were recruited from 2 regions near the airport
- 40 participants were recruited in Philadelphia from areas without relevant amounts of air-traffic
- The control region was selected to have similar socio-demographic and road traffic characteristics
- Participants were primarily recruited by mailing flyers
- Participants were screened over the phone to determine eligibility



Study Methodology

- The study for each participant lasted 4 consecutive days/3 nights starting either on a Monday or Tuesday
- Staff members went to the participants home on the first night to setup equipment and explain the protocol and returned after the third night to collect the equipment
- Staff members were available throughout the study by cell phone to address any questions or concerns
- Participants could go to sleep at their normal times and wake up at their normal times
- Participants could go about normal activities during the day
- We asked that participants turn off any noise producing items including TV, radio, music, etc. when they slept

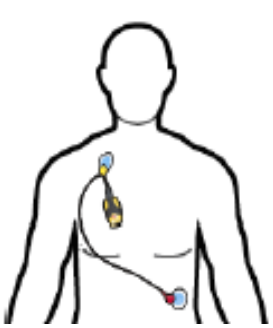
Surveys

- On the first day of the study the following surveys were filled out:
  - SF-36 Health Survey
  - Pittsburgh Sleep Quality Index (PSQI)
  - Horne-Ostberg Morningness-Eveningness Survey: Measure of chronotype e.g. morning lark or night owl
  - Survey to obtain socio-demographic characteristics
- Each morning participants completed a survey on their previous nights sleep and their level of fatigue

Physiological Measurements

ECG + Actigraphy: 3 Nights

- ECG was sampled at 1kHz and the peak of each R-wave was detected and recorded
- Movement was measured with a 3 axis accelerometer, sample rate of 10 Hz



Blood Pressure Measurements: 3 Mornings

- A home monitor was used by participants
- 3 measurements were completed each morning with 1 minute between measurements

Environmental Measurements

Temperature, Light, and Humidity: Continuously

- The device was placed near the head of the bed on a nightstand or dresser
- Values were recorded every 1 minute

Outdoor Noise Measurements: Continuously

- A small audio recorder was placed outside near the participant's bedroom window, either on the window ledge or on a weighted tripod
- '.wav' files saved

Indoor Noise Measurements: Continuously

- One second L_{Aeq} and unweighted one-third octave band levels were recorded continuously throughout the study
- Participants turned on an additional recorder which saved '.wav' files of the sounds at night

Participant Characteristics

- 79 of 80 participants enrolled completed measurements
- Participants were from 56 different households

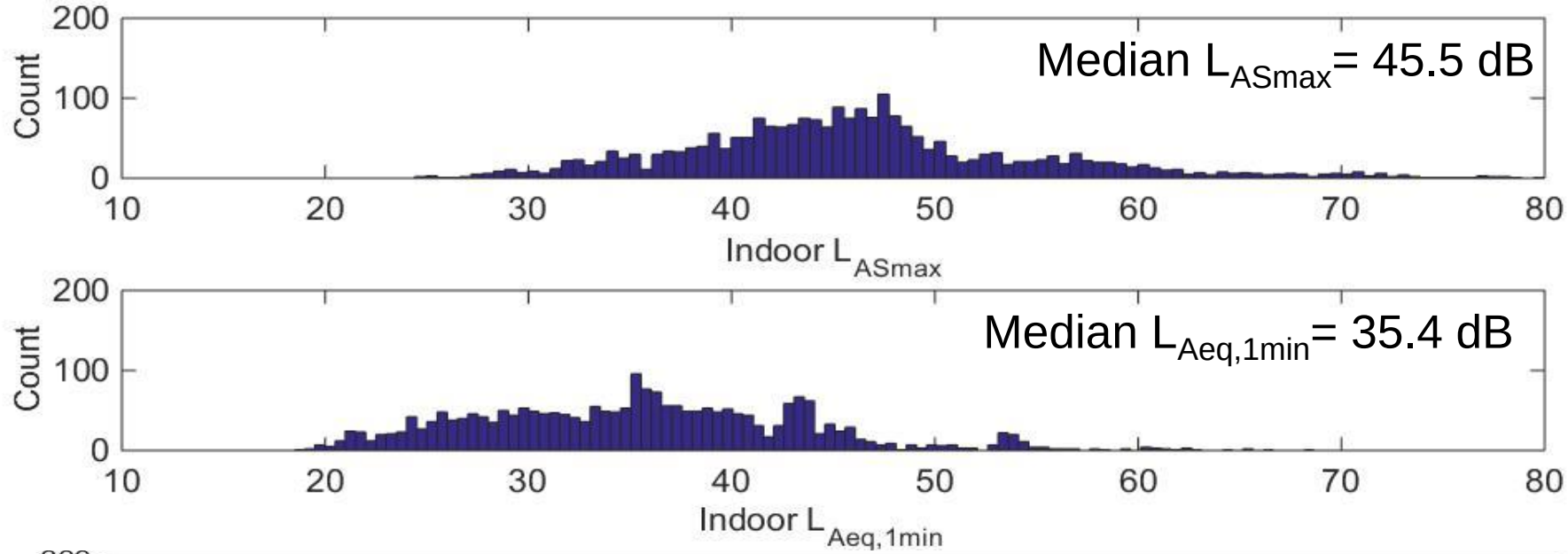
	Aircraft Noise Region (n=39)	Control Region (n=40)
Age (mean, range)	46, 22-77	32, 22-68
Gender (% Male)	41%	48%
Education Level (% that had at least some college)	67%	90%
Duration of Residence (mean)	11 years	6 years
% Noise Sensitive	13%	10%

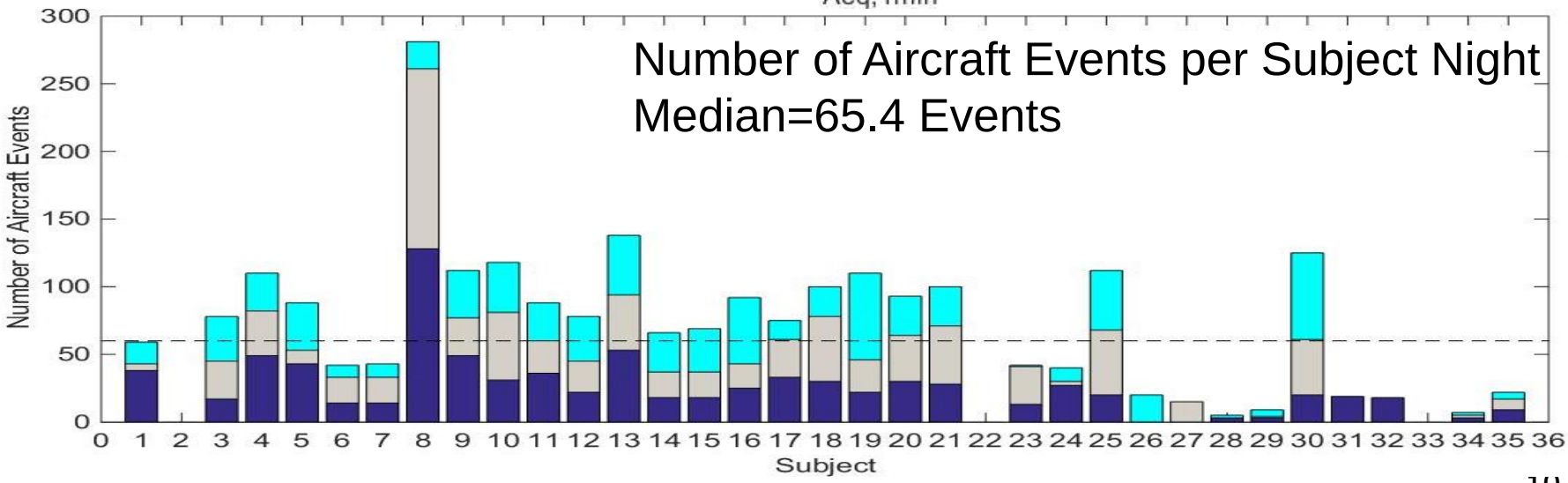
Feasibility of Study Protocol

227 Days/Nights of Data Collected	
ECG and Actigraphy Measurements	93% of the nights, no missing periods of data
Blood Pressure Measurements	93% of the mornings, all three measurements completed
Sound Recordings	89% of the nights, full sound recordings obtained
Surveys	All questionnaires were completed

Aircraft Noise Levels

Events identified using flight operations data and verified by human scorer

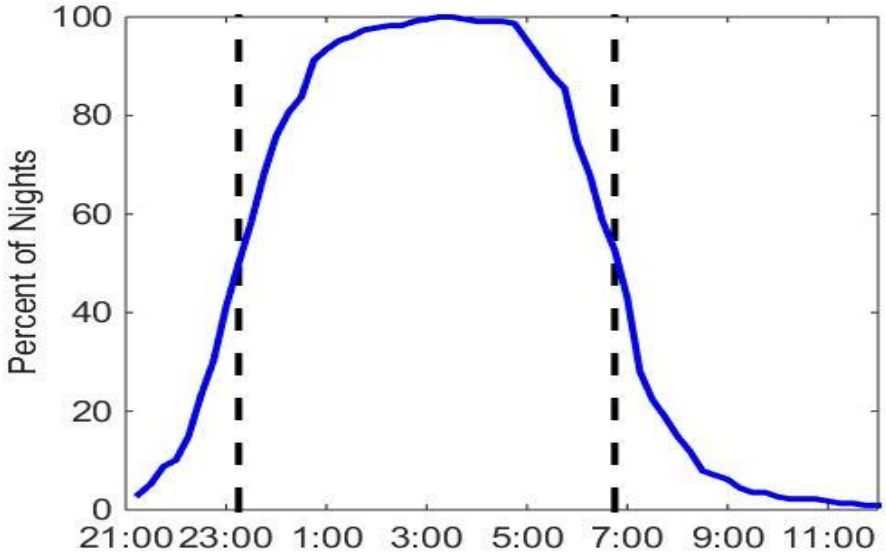




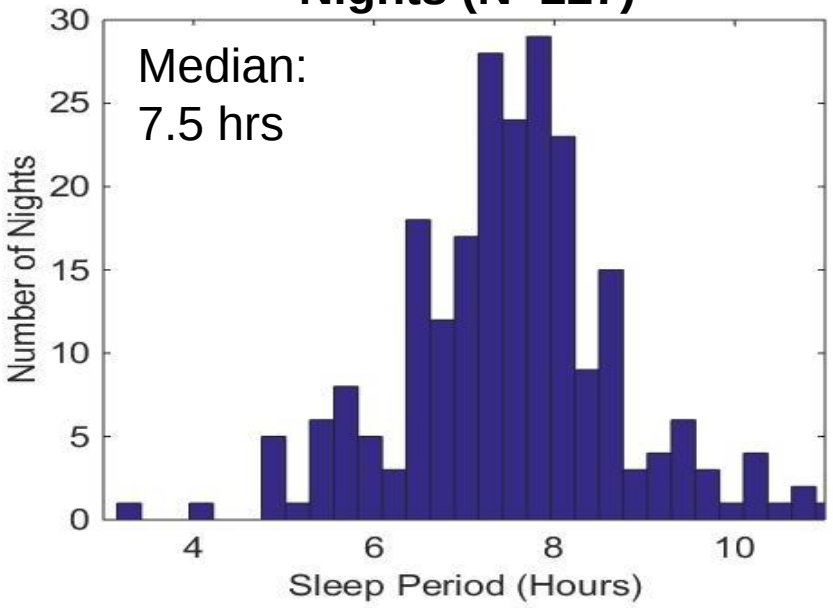
Sleep Parameters for the Entire Night

- Awakenings were identified automatically based on the heart rate and actigraphy data (software was developed by research team).
- Artifacts were visually identified and removed from analysis
- During periods in which the heart rate signal was invalid (6% of nights), awakenings were identified based on movement only

Percentage of Sleeping Participants



Sleep Period Duration-Distribution for All Subject Nights (N=227)



Awakening Analysis

Linear mixed model results for the **Sleep Fragmentation Index (SFI)**:

Sleep Fragmentation Index: # of awakenings divided by sleep period time (hours)

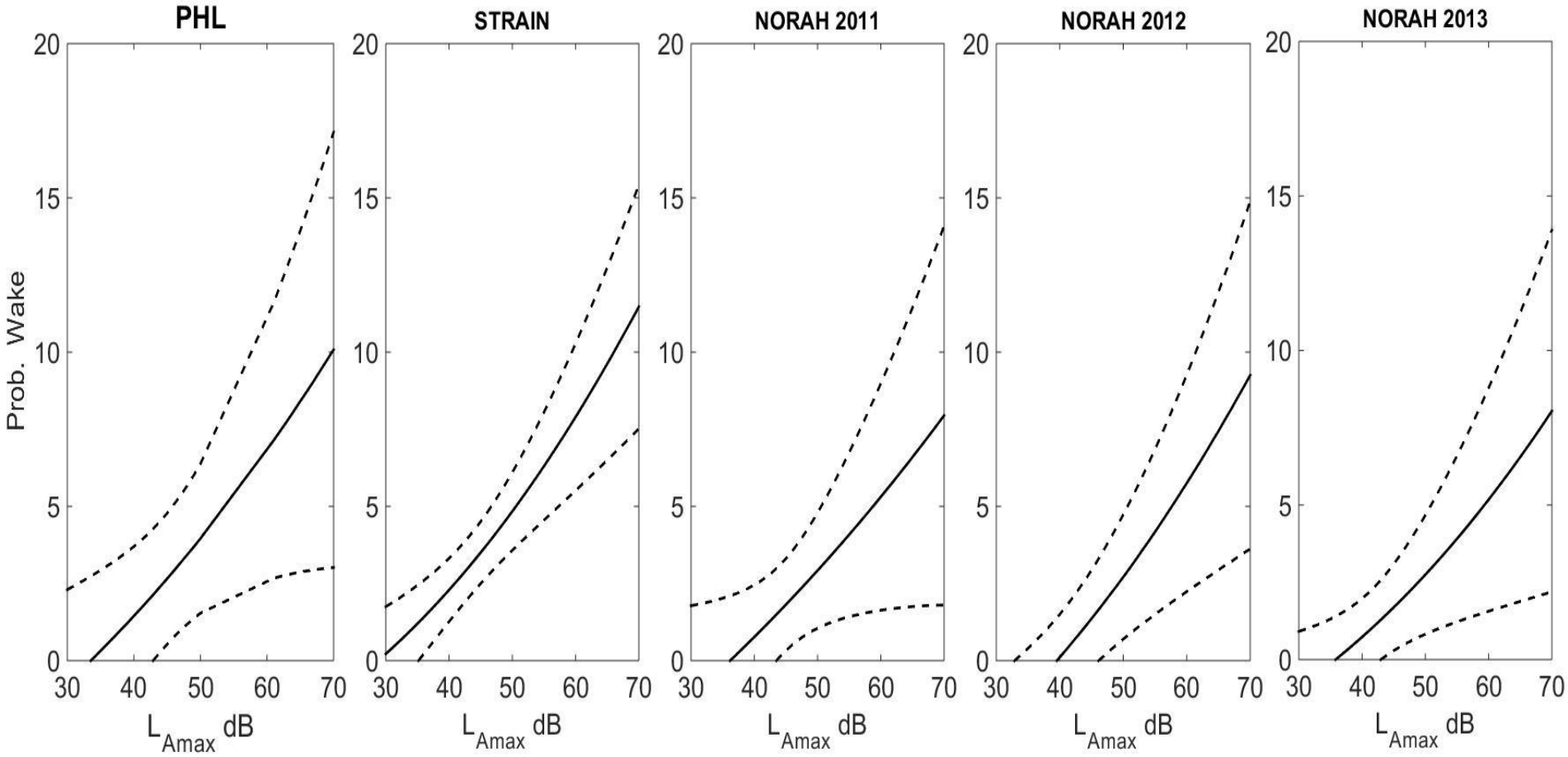
	Model			Model 2		
Moderators	**Coefficient Estimate**	**Standard Error**	**p-value**	**Coefficient Estimate**	**Standard Error**	**p-value**
Age	-0.0363	0.01597	0.0260	-0.0358	0.0160	0.0285
Male	0.5205	0.4234	0.2230	0.6816	0.4280	0.1160
BMI	-0.0057	0.05372	0.9158	0.0153	0.0543	0.7791
Airport	0.1850	0.4760	0.6986			
L_{Aeq} [dB]				0.0036	0.02422	0.8809

Logistic regression models for the **probability of awakening**:

	Model 1			Model 2		
Moderators	**Coefficient Estimate**	**Standard Error**	**p-value**	**Coefficient Estimate**	**Standard Error**	**p-value**
L_{ASmax} [dB]	0.01985	0.0076	0.0136	0.02011	0.0073	0.0094
Age				-0.0072	0.0045	0.1217
Male				0.1902	0.1537	0.2253
Time (min)				0.001203	0.000366	0.0025

Exposure-Response Models

- Spontaneous awakening probability (during noise free periods) was 12.2%
- Exposure-Response relationships are for unadjusted models



Morning Blood Pressure Measures

- Systolic and Diastolic blood pressure levels were averaged across all 3 measurements for each morning
- Linear mixed models adjusted for age, gender, BMI and region were calculated
- Systolic Blood Pressure:
  - Increased significantly with age ($p<0.0001$)
  - Increased significantly with BMI ($p=0.0159$)
  - Significantly higher in male participants ($p<0.0001$)
  - No significant association with region (airport vs control) ($p=0.3255$)
- Diastolic Blood Pressure:
  - Increased significantly with age ($p=0.0009$)
  - Increased significantly with BMI ($p=0.0011$)
  - No significant association with gender ($p=0.0896$)
  - No significant association with region (airport vs control) ($p=0.7108$)

Self-Report Measures (1)

PROMIS-Sleep Questions

- Questions referred to the past month
- Response scales ranged from never(1) to always(5)
- Linear mixed models adjusted for age, gender, BMI and region

Coefficient Estimates are for Airport Region			
	Coefficient Estimate	**Standard Error**	**p-value**
My sleep was restless	0.2056	0.2163	0.3450
I was satisfied with my sleep	-0.3522	0.2279	0.1266
My sleep was refreshing	-0.4698	0.2059	0.0255
I had difficulty falling asleep	0.5771	0.2551	0.0267
I had trouble staying asleep	0.3472	0.2736	0.2086
I had trouble sleeping	0.3200	0.2300	0.1684
I got enough sleep	-0.4612	0.1991	0.0235

Self-Report Measures (2)

Pittsburg Sleep Quality Index

- PSQI retrospectively assesses sleep quality over a period of a month
- Responses to individual questions were combined to obtain a global score which ranges from 0 (indicating best sleep quality) to 21 (indicating worst sleep quality)

Linear Mixed Model for Global PSQI Score			
Moderators	**Coefficient Estimate**	**Standard Error**	**p-value**
Age	0.0094	0.02110	0.6573
Male	-0.4071	0.5600	0.4697
BMI	0.1473	0.07110	0.0420
Airport Region	1.5227	0.6287	0.0180

- Scores > 5 are typically used to distinguish poor quality sleep from high quality sleep
- 60.5% in the airport region reported a PSQI score > 5 in the airport region compared to 18.4% in the control region (p=0.0061)

Self-Report Measures (3)

SF-36 Health Survey

- Participants were asked how true or false each of the statements were in the table below
- Response categories were Definitely true (5), Mostly true (4), Don't know (3), Mostly false (2), and Definitely false (1)
- Linear mixed models adjusted for age, gender, BMI and region

Coefficient Estimates are for Airport Region			
	Coefficient Estimate	**Standard Error**	**p-value**
I seem to get sick a little easier than other people.	0.1548	0.2635	0.5586
I am as healthy as anybody I know.	-0.1939	0.2486	0.4380
I expect my health to get worse.	0.6035	0.2739	0.0308
My health is excellent.	-0.6145	0.2228	0.0074

Morning Surveys

No significant difference between airport and control region for ratings of:

- Fatigue (p=0.3481)
- Difficulty falling asleep (p=0.9724)
- Sleep quality (p=0.3231)

Discussion (1)

- There was ~10% of data loss which demonstrates the feasibility of unattended physiological measurements and noise measurements
- No significant difference was found between regions for morning blood pressure measurements or self-reported measures of sleep and fatigue on the morning survey
- Those living near the airport reported poorer sleep quality reflected in responses to the PROMIS and PSQI sleep questions and poorer health as reported on the SF-36
- Awakening probability increased statistically significantly with the L_{ASmax} of aircraft noise events
- No significant difference was found between regions for the sleep fragmentation index
  - Airport residents may have been able to compensate for noise-induced awakenings during noise-free intervals
  - The ECG-based algorithm is less sensitive in older subjects

Discussion (2)

- Study Methodology Limitations:
  - Low Response Rate:
    - 3700 flyers were mailed to obtain target enrollment of 80
    - Individuals may have been reluctant to allow unknown staff in their home to setup equipment
  - Methodological Expense:
    - Staff Costs: Staff were in the field for 2 to 4 days per week
    - Equipment Costs: Sound recording equipment can be expensive. This can restrict the number of sites that can be studied concurrently.
- Based on the lessons learned, the methodology has been modified and a second pilot study will be conducted

Year 2 Sleep Study

- To increase response rate:
  - Brief recruitment survey will be mailed: Primary purpose is to determine eligibility for physiological measurements
  - Participants will be compensated for completing the survey: Amazon gift card of $2.00, $5.00, or $10.00
  - For in-home measurements staff will not need to enter participants home
- To reduce methodological cost:
  - Equipment will be mailed to the participant's homes
  - Sound recording equipment: Portable audio recorder with class 1 microphone instead of class 1 sound level meter
  - Total equipment cost for 1 setup $1,130

Status: Measurements to Begin Fall 2016

Acknowledgements

- Volpe National Transportation Systems Center provided the sound recording equipment used for the indoor measurements in the Philadelphia Sleep Study
- We have a cooperative agreement with DLR. The ECG and actigraphy methodology was jointly refined with colleagues from DLR.

Publications

- McGuire S, Witte M, and Basner M. Evaluation and refinement of a methodology for examining the effects of aircraft noise on sleep in communities in the US. Inter-noise, Hamburg, Germany, 2016.

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