



U.S. Department of Transportation
Federal Aviation Administration

FINAL PROJECT REPORT

Form Approved:
O.M.B. No. 2120-0559
9/30/2013

PART I - PROJECT IDENTIFICATION INFORMATION

1. Institution and Address	2. FAA Program	3. FAA Award Number
	4. Award Period From To	5. Cumulative Award Amount
6. Project Title		

PART II - SUMMARY OF COMPLETED PROJECT (For Public Use)

--

PART III - TECHNICAL INFORMATION (For Program Management Uses)

1. ITEM (Check appropriate blocks)	NONE	ATTACHED	PREVIOUSLY FURNISHED	TO BE FURNISHED SEPARATELY TO PROGRAM	
				Check (X)	Approx. Date
a. Abstracts of Theses					
b. Publication Citations					
c. Data on Scientific Collaborators					
d. Information on Inventions					
e. Technical Description of Project and Results					
f. Other (specify)					
2. Principal Investigator/Project Director Name (Typed)	3. Principal Investigator / Project Director Signature			4. Date	

Part III of Report 9550-5:

c.) Scientific Collaborators

- Sarah McGuire-Co-Investigator
Research Assistant Professor, Department of Psychiatry, University of Pennsylvania
- Maryam Witte-Assistant
Research Assistant, Department of Psychiatry, University of Pennsylvania

e.) Technical Description of Project and Results

Project Report Attached

Pilot Sleep Study near Philadelphia International Airport

ASCENT Project 17 Report

Research Supported by: 13-C-AJFE-UPENN-001 and 13-C-AJFE-UPENN-002

Report Date: August 2016

Project Period: September 2013 – August 2016

Principal Investigator: **Mathias Basner, MD, PhD, MSc**

Co-Investigator: **Sarah McGuire, PhD**

Technical Support: **Maryam Witte**

University of Pennsylvania Perelman School of Medicine
Philadelphia, PA

Table of Contents

1.	Summary	4
2.	Introduction.....	6
3.	Measurement Site Selection.....	7
3.1	Airport Selection and Noise Modeling.....	7
3.2	Control Region Selection	10
3.3	Participant Sampling Regions	13
4.	Study Methodology.....	14
4.1	Physiological Measurements.....	14
4.2	Environmental Measurements.....	16
4.3	Subjective Assessments.....	17
4.4	Additional Protocol Instructions	18
4.5	Subject Recruitment	18
5.	Participants and Data Overview.....	19
5.1	Participant Characteristics.....	19
5.2	Feasibility of Study Protocol.....	20
6.	Acoustic Analysis	22
6.1	Aircraft Event Scoring	22
6.2	Aircraft Noise Levels	24
7.	Statistical Methods.....	25
8.	Heart Rate and Actigraphy Analysis.....	26
8.1	Heart Rate and Actigraphy Awakening Identification Program	26
8.2	Descriptive Sleep Parameters of the Entire Night.....	26
8.3	Single Event Awakening Analysis.....	28
9.	Blood Pressure Measurement Analysis	30
10.	Self-Reported Results	31
10.1	PROMIS Sleep Questions	31

10.2	SF-36 Health Survey	31
10.3	Pittsburgh Sleep Quality Index (PSQI)	32
10.4	Morning Survey	33
11.	Discussion	33
12.	Outlook	34
13.	Acknowledgements	35
14.	References	36
15.	Appendix	38
15.1	Mailed Recruitment Flyer	38
15.2	Screening Survey	39
15.3	PSQI Survey	41
15.4	SF-36 Survey	44
15.5	Morningness-Eveningness Survey	48
15.6	Demographic Survey	52
15.7	Morning Survey	57

1. Summary

Aircraft noise can disturb sleep and impair recuperation. An inexpensive yet sound study methodology is needed for field studies on the effects of aircraft noise on sleep. These studies are needed for developing exposure-response relationships that are representative of noise exposed communities around multiple airports and that can be used to inform policy. In collaboration with colleagues from the German Aerospace Center (DLR), we developed a methodology to monitor sleep and identify awakenings using ECG and actigraphy. ECG electrodes and actigraphs are non-invasive and can be easily applied by the investigated subjects themselves therefore greatly reducing the methodological study cost. We developed an automatic algorithm based on ECG and actigraphy data which predicts awakenings based on both body movements and changes in heart rate, and were able to show that the automatic scorings of the algorithm agree closely with awakenings identified using polysomnography (the current gold standard for measuring sleep and related events).

This report describes the design and results of a pilot field study on the effects of aircraft noise on sleep conducted in the vicinity of Philadelphia International Airport (PHL) using the methodology described above. Eighty participants were recruited, 40 from a region with aircraft noise exposure near the airport and 40 from a control region in Philadelphia County. Control region participants were comparable to the exposed group of subjects in terms of sociodemographic characteristics and non-aircraft traffic exposure, but without relevant amounts of nighttime air-traffic. Participants were primarily recruited by mailing flyers. After obtaining informed consent and gathering baseline characteristics, each participant completed three consecutive nights of ECG and actigraphy measurements with concomitant noise level measurements and sound recordings each night in his/her bedroom. Additionally, participants measured their blood pressure and completed brief questionnaires subjectively assessing their sleep each morning. All objective and subjective measurements was completed unattended, staff only went to the participant's home on the first and last day of the study to setup and collect the equipment.

The objectives of this study were the following:

Aim 1: Evaluate the completeness and quality of data obtained through unattended sleep measurements. This was the primary objective of the study.

Aim 2: Compare the degree of sleep fragmentation, subjective sleep ratings, and subjective health ratings between the airport and control region.

Aim 3: Develop models relating awakenings to indoor noise levels, and compare results to models derived from similar studies conducted by DLR in Germany.

Aim 4: Further refine study protocol and methodology based on lessons learned for a potential future multi-airport US field study on the effects of aircraft noise on sleep.

79 of 80 participants enrolled in the study completed the measurements, and all but 1 of the 79 completed all three nights of the study. For all physiological and noise measurements, there was 10% data loss or less, which suggests that participants were able to follow the study protocol unattended.

Linear mixed models were calculated, controlling for age, gender, and BMI, to examine differences in objectively measured sleep, morning blood pressure measurements, and subjective assessments of sleep and health between participants that lived near the airport and those in the control region. The sleep fragmentation index (SFI; calculated based on the ECG and actigraphy data) did not differ statistically significantly between the two groups of participants. It is possible that subjects were able to compensate for aircraft noise-induced awakenings (see below) during noise-free intervals. We found significant differences between the two participant groups for subjective sleep and health ratings, with individuals living near the airport reporting poorer sleep quality (based on the PSQI survey and PROMIS sleep questions) and poorer health (based on the SF-36 survey). However, no statistically significant difference in either systolic or diastolic blood pressure between airport and control regions was found.

Single event awakening analysis based on random effect logistic regression was conducted to examine whether the indoor noise level of single aircraft events (L_{ASmax}) was related to awakenings determined with the ECG and actigraphy. The coefficient for L_{ASmax} was positive and statistically significant (i.e., higher noise levels were associated with increased awakening probability), and the results were similar to those found in 2 studies conducted by the German Aerospace Center in the vicinity of Cologne-Bonn airport (STRAIN study) and Frankfurt airport (NORAH study). One limitation of the derived exposure-response relationship is the wide confidence interval due to the small sample size and the comparatively low number of events per subject in this pilot study.

The results of this study indicate that the protocol needs further refinement for a potential future multi-site US field study on the effects of aircraft noise on sleep. While the target enrollment was met, the response rate was low (80 subjects recruited from 3,700 mailings). For results to be representative of the exposed population, the response rate needs to be increased. A completely unattended study design where equipment is mailed to and from study participants is currently being explored in a follow-up study. In addition, larger sample sizes and a wider range of noise

levels are needed to obtain more precise exposure-response functions for health impact assessments.

2. Introduction

The most recent US sleep studies on the effects of aircraft noise on sleep date back to 1996. Since then US air traffic has changed significantly, with substantial increases in traffic volume, and significant reductions in noise levels of single aircraft. Due to inter-cultural differences and different operational procedures, results from studies performed outside the US may not transfer directly to US domestic airports. Therefore, it is important that field studies be conducted in the US to acquire current data on sleep disturbance relative to varying degrees of noise exposure.

The gold standard for measuring sleep is polysomnography, which is the simultaneous measurement of brain potentials (electroencephalogram, EEG), eye movements (electrooculogram, EOG), and muscle tone (electromyogram, EMG). Sleep stages are identified based on specific patterns in the physiological signals for each 30-second segment of the night.¹ Wake is differentiated from sleep, and Rapid Eye Movement (REM) sleep is differentiated from non-REM (stages S1 through S4). Stages S1 and S2 (N1 and N2 in the newer AASM criteria²) are considered light sleep and S3 and S4 (N3 in the AASM criteria) are considered deep sleep. Shorter activations in the EEG and EMG of 3 seconds or longer can also be scored and are referred to as cortical arousals.

Polysomnography has been implemented in a few field studies on the effects of road, rail, or aircraft noise on sleep.³⁻⁶ However, it is expensive to implement as trained staff are needed to apply and remove the electrodes. Trained staff is also needed to visually score sleep stages which has both high intra- and inter-rater variability.^{7,8} Also, the methodology is somewhat invasive and may influence sleep itself, especially during the first night(s).⁹ A less invasive method for monitoring sleep is actigraphy which infers sleep and wake patterns from body movements, measured using a wrist worn device. While this approach is noninvasive and less expensive, analysis is typically based on 60-second segments and different algorithms are used to score the data. Compared to polysomnography, actigraphy has a high sensitivity in identifying sleep epochs but a low specificity in identifying wake epochs.¹⁰

Awakenings are typically associated with arousals of the autonomic nervous system, which include increases in heart rate and blood pressure. Basner et al.¹¹ previously developed an algorithm for automatically identifying cortical arousals of 3 seconds or longer in duration based on increases in heart rate alone. These brief arousals can occur over 80 times a night without noise exposure, therefore they are not considered a specific indicator of noise-induced sleep

disturbance.¹² Therefore, during an earlier period of this project, this algorithm was refined in order to only identify cortical arousals that are 15 seconds or longer in duration,¹³ which is the indicator of noise-induced sleep disturbance most commonly used in the field and a more specific indicator of sleep disruption.¹⁴ Body movements measured with actigraphy were also newly included in the algorithm. Agreement between cortical arousals identified visually based on polysomnography data and arousals identified using the refined ECG- and actigraphy-based algorithm was evaluated by calculating Cohen's Kappa, which represents agreement corrected for chance. A Kappa value of greater than 0.80 was found which is considered "near perfect" agreement between the two approaches according to conventional standards.¹⁵ An advantage of using ECG and actigraphy only for monitoring sleep is that participants can apply the equipment themselves; therefore reducing the methodological study cost as staff is not needed in the field each night and morning. In addition, the combined ECG/actigraphy device used in this study requires 2 chest electrodes (1 derivation of the ECG) only compared to the multiple electrodes and wires that are required for polysomnographic sleep studies which may have an effect on an individual's sleep quality. Finally, the algorithm that was developed allows arousals to be identified automatically and consistently across studies.

The methodology of using ECG and actigraphy to monitor sleep was implemented in a pilot study that was conducted around Philadelphia International Airport (PHL). Eighty participants were enrolled in the study, with each participant completing three nights of unattended sleep measurements. Forty of the participants were recruited from regions near PHL airport and 40 were recruited from regions without relevant air-traffic in Philadelphia County. The primary objective of this study was to evaluate the feasibility of the study methodology, in particular the quantity and quality of data that could be obtained when participants use physiological and noise measurement equipment unattended. A secondary objective of this study was to compare objective and subjective measures of sleep and health between control and aircraft noise exposed groups.

3. Measurement Site Selection

3.1 Airport Selection and Noise Modeling

For this study, staff needed to go into the field to deploy and collect equipment. Therefore airports within proximity of the University of Pennsylvania were considered. In addition, the airport had to have relevant amounts of nighttime air-traffic. Operations around PHL were examined in order to determine whether it met this requirement. PDARS (Performance Data Analysis and Reporting System) data was obtained from the FAA for PHL and 4 months of data from June 2012 to September 2012 were modeled. The average number of hourly operations was

calculated for 68 nights (Figure 3.1). There were 130 events between 11:00 pm and 7:00 am, with cargo operations in the middle of the night between 3:00 to 4:00 am.

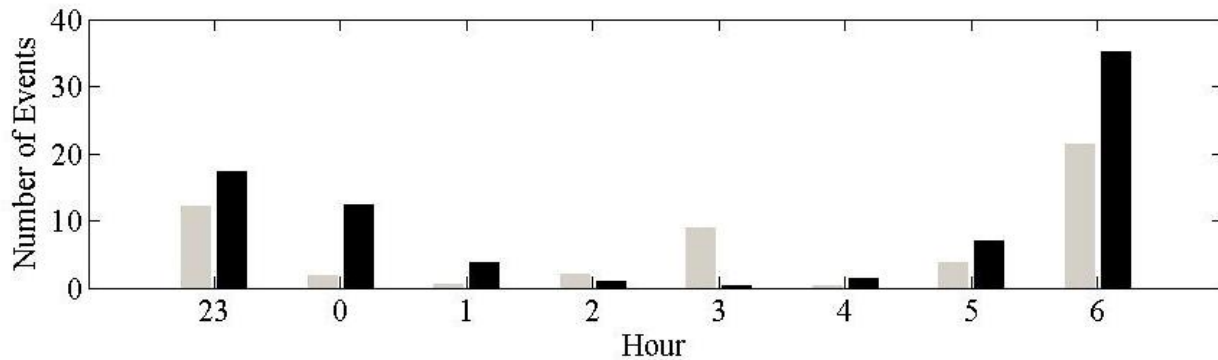


Figure 3.1: Average number of hourly operations at Philadelphia International Airport based on 68 nights of modeled data (period June 2012 to September 2012). Departures (gray) and arrivals (black).

For each of the 68 nights it was also determined whether the airport was operating predominately in the East flow or West flow direction. For the East flow, the departures and arrivals are on runways 08, 09L, and 09R. For the West flow, the departures and arrivals are on runways 26, 27R, and 27L. The primary direction for 9 nights that were modeled was in the East flow and for 59 nights in the West flow. L_{night} contours were calculated for each of 68 nights using INM 7.0d. The average L_{night} contour for the East flow and the West flow directions was calculated (Figure 3.2).

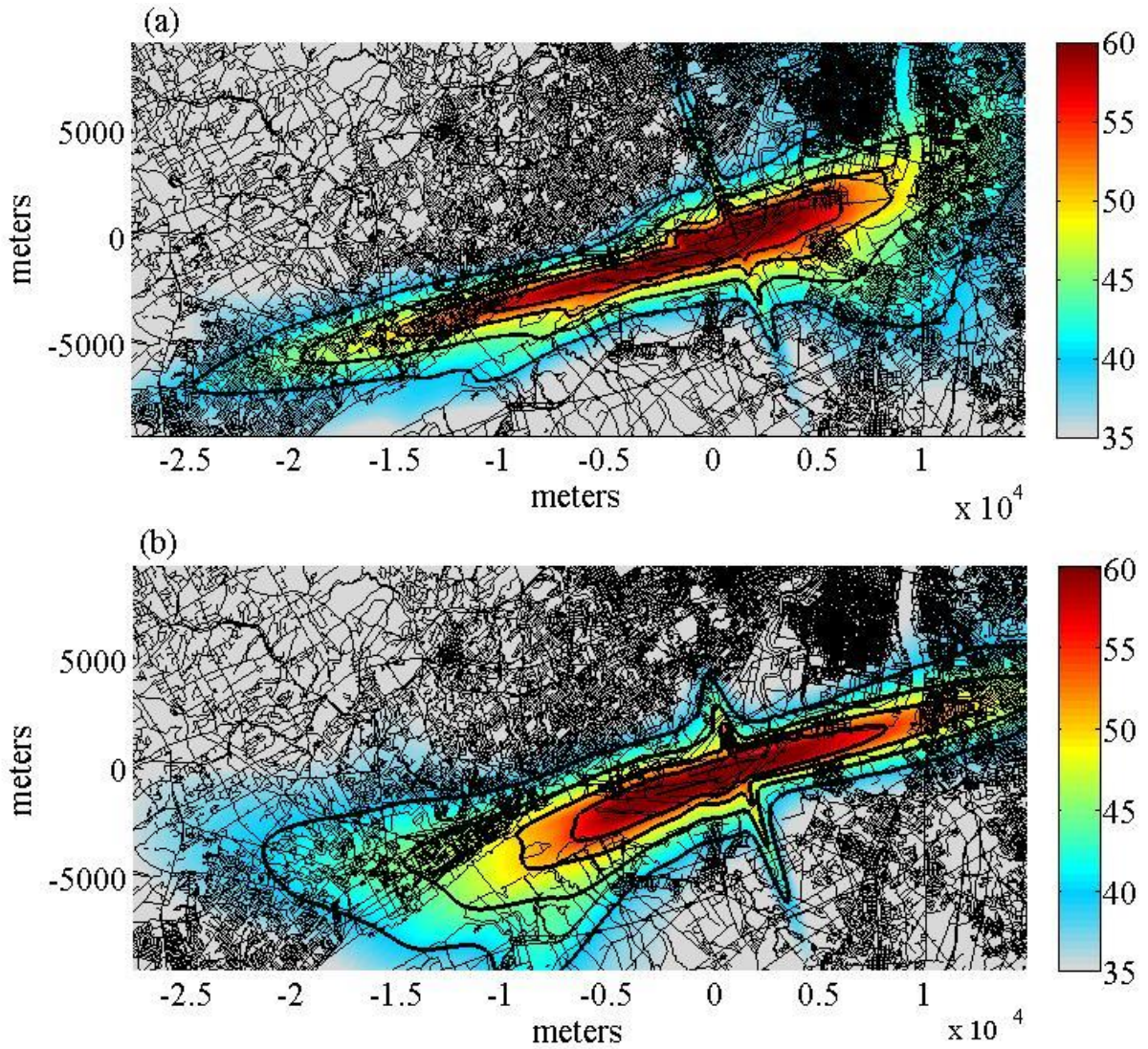


Figure 3.2: Average L_{night} contours for (a) East flow configuration (13.2% of modeled nights) and (b) West flow configuration (86.3% of modeled nights). The contour lines shown are the 40, 45, 50, and 55 dB(A) L_{night} contours.

The total population within each contour was calculated using block level population data from the 2010 US Census, listed in Table 3.1. As PHL had a sufficient number of nighttime flight operations and a large enough exposed population to sample from, it was selected as the site for the study.

Table 3.1: Number of residents within each L_{night} contour

L_{night}	Average East [N=9]	Average West [N=59]
≥ 55 dB(A)	345	249
50-55 dB(A)	15,627	8,901
45-50 dB(A)	39,183	41,596
40-45 dB(A)	278,672	83,011

3.2 Control Region Selection

The control region was selected based on socio-demographic and noise characteristics of the region in comparison to the aircraft noise exposed region around PHL. The sociodemographic data used was from the US Census 2012 American Community Survey. The data for Delaware, Philadelphia, and Montgomery County was obtained and plotted on the geographic level of US census tract (Figure 3.3). We wanted to select a region that had similar sociodemographic characteristics as Tinicum Township near PHL, which is predominately Caucasian with a median yearly household income of \$53,000.

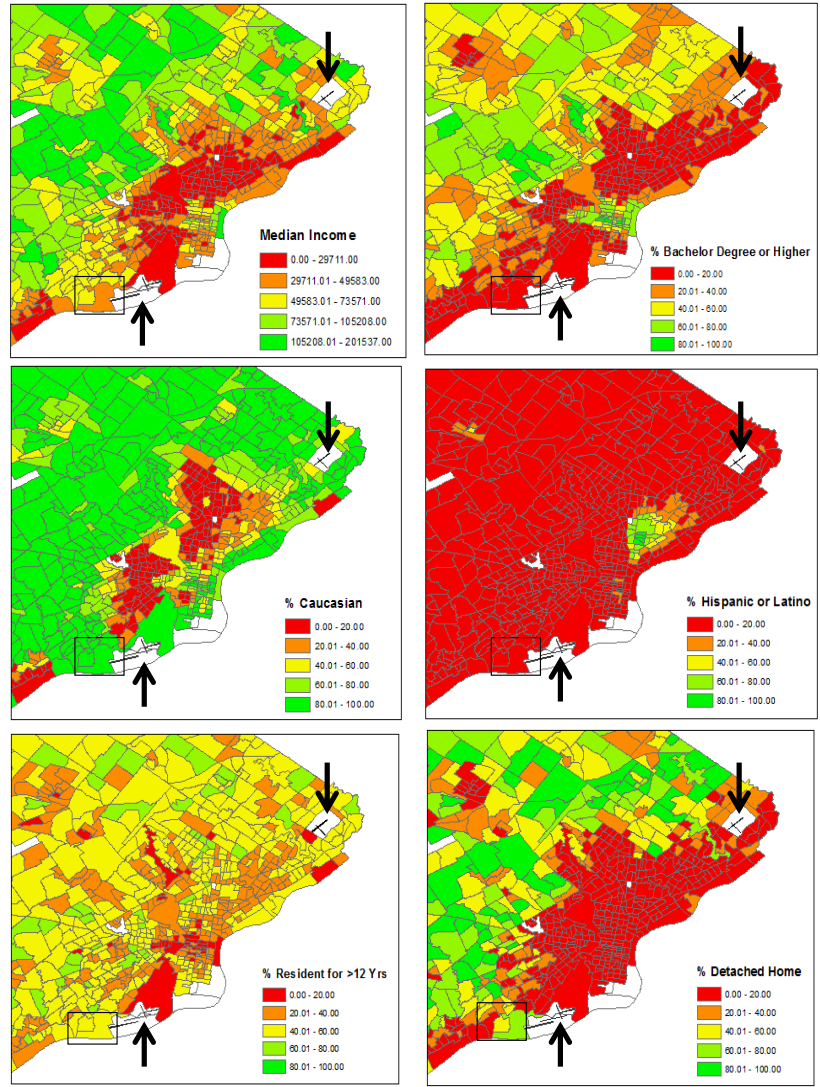


Figure 3.3: Sociodemographic characteristics of Delaware, Montgomery and Philadelphia County from the 2012 American Community Survey. The primary aircraft-noise exposed sampling region for the study is indicated by the black box in each panel. The two airports are indicated by arrows.

In the region there are two airports, the runways for both are indicated in the maps. The primary airport is PHL. The other airport is Northeast Philadelphia Airport which is a general aviation airport situated in the North of Philadelphia. Using INM, the maximum noise levels for single aircraft events were calculated for the centroid of each census block. The noise level in each census tract was determined by calculating the mean of the census block levels. The number of events above a L_{ASmax} noise level of 50 dB and 60 dB was also calculated (Figure 3.4). Census tracts in which there were less than 5 events with a maximum noise level above 50 dB, were predominately Caucasian, and had a median income within 25% of the median income of Tinicum

Township were identified as potential control sites. Many of the identified sites were near Northeast Philadelphia Airport and therefore could not be used for the control area. One region in Northwest Philadelphia County was selected as the control site (Figure 3.5).

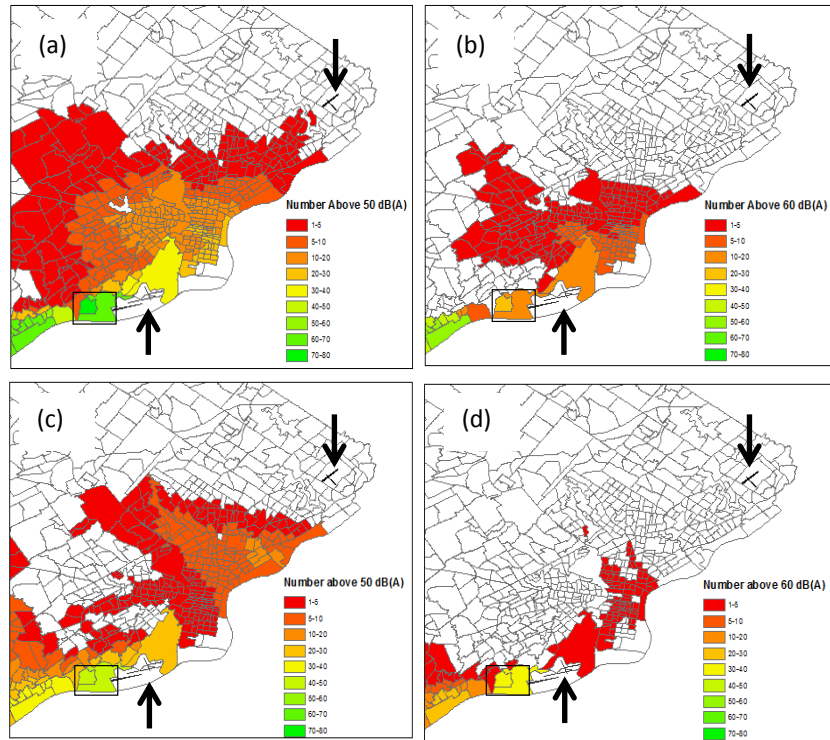


Figure 3.4: Number of events above a L_{ASmax} of 50 dB and 60 dB for (a,b) East flow configuration and (c,d) West flow configuration. The primary aircraft-noise exposed sampling region for the study is indicated by the black boxes. The two airports are indicated by arrows.

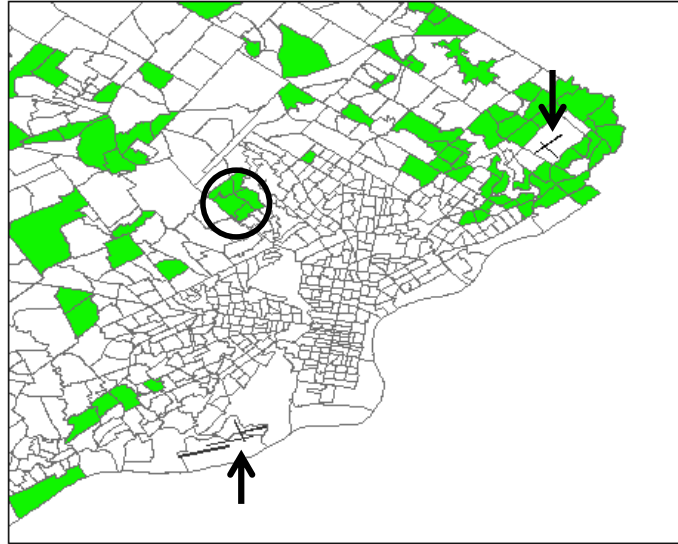


Figure 3.5: Potential control areas identified which have less than 5 events with a L_{ASmax} level above 50 dB, are predominately Caucasian, and have a median income similar to the noise-exposed sample region. The selected control region is indicated by a black circle. The two airports are indicated by arrows

3.3 Participant Sampling Regions

The original selection of sample regions was Tinicum Township in Pennsylvania which is directly west of the airport and a control region in west Philadelphia that had similar sociodemographic characteristics. However, to meet our participant requirements near the airport we also recruited participants from Gloucester City, New Jersey, situated east of the airport. This region had comparable sociodemographic characteristics as Tinicum Township. All three sampling regions are shown in Figure 3.6.

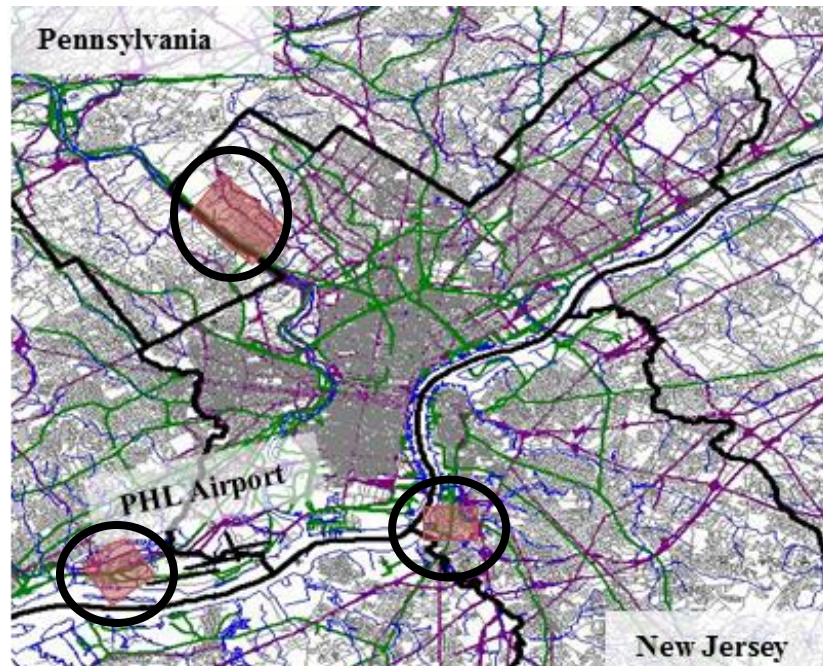


Figure 3.6: Measurement regions for the pilot sleep study conducted near Philadelphia International Airport. Measurement areas are highlighted in red.

4. Study Methodology

The protocol of the pilot study was approved by the Institutional Review Board of the University of Pennsylvania (Protocol #819770). The study for each participant lasted for 4 days/3 consecutive nights and either took place on Monday thru Thursday or Tuesday thru Friday, depending on the participant's availability. This study was restricted to weeknights only for consistency across the 3 nights for each subject, as bedtime, sleep duration, and flight schedules may be different on weekends. Two staff members went to the participant's home on the first night of the study to explain the study protocol and walk participants through equipment use, obtain written informed consent, and setup equipment for monitoring the noise. It took approximately 1-2 hours for each setup. The study measurements were then completed unattended for the next three nights, with staff members returning after the third night to collect the equipment which required approximately 30 minutes time. Staff members were available throughout the study via cell phones to address any questions or concerns that participants had.

4.1 Physiological Measurements

During the night, participant's sleep was monitored using one device (eMotion Faros 90) which measured both heart rate and body movements (Figure 4.1). The device was battery powered and attached with two electrodes to the chest of the subjects. The ECG was sampled at

1 kHz and the peak of each R-wave was detected and recorded. Movement was also measured using a 3-axis accelerometer at a sample rate of 10 Hz, 14 bit resolution. As movement was recorded with a high resolution, breathing patterns could be inferred from movements of the chest and it could be determined whether participants had chest movements that would be suggestive of sleep apnea during the night.

To examine potential consequences of noise-induced sleep disturbance, each morning participants completed blood pressure measurements in an upright seated position using a home monitor with pre-formed arm cuff for 9-17 inches (Omron BP791IT). Three consecutive measurements were taken automatically with one minute intervals between measurements. Participants were told not to drink caffeine, smoke, or exercise, and to be sitting in a state of rest for 5-10 minutes before completing the measurements (Figure 4.2).

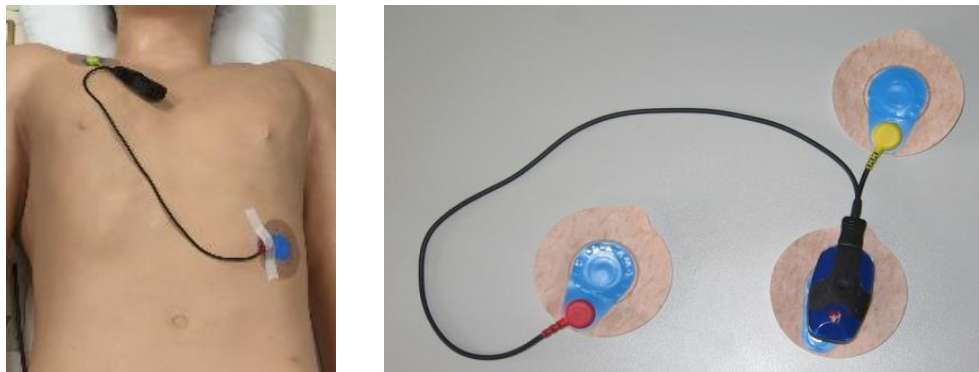


Figure 4.1: Faros 90 actigraphy and heart rate monitor worn each night by participants



Figure 4.2: Omron blood pressure monitor BP791IT used each morning by participants

4.2 Environmental Measurements

To monitor the noise in the participant's bedroom, one microphone was setup near the head of the bed (Figure 4.3). The height of the microphone was 1 foot above the mattress, i.e. approximately the height of the participants head on the pillow. Due to furniture in the room, it was not always possible to place the microphone directly next to the pillow, sometimes it had to be set up at the foot of the bed so that the participants could move around their bedroom comfortably (Figure 4.3). One second L_{Aeq} levels and unweighted one-third octave band levels were recorded 24 hours a day throughout the study using a class-1 sound level meter (Larson and Davis Sound Level Meter 831). At night before going to bed, participants turned on an additional sound recorder (Roland R-05) which saved standard resolution audio recordings (16-bit, 44100 Hz, .wav files) of the sounds inside the bedroom. Sound recordings during the night were made so that the source of noise events could be determined. If there were two participants in the same room, only one microphone and set of sound recording equipment was used. Participants were instructed to start and stop the sound recorder when the first person retired to bed and after the last person woke up in the morning, respectively.

A less expensive audio recorder (Tascam DR-07) was placed outside near the participant's bedroom window, which also recorded sounds. Standard resolution audio recording files were saved (16 bit, 44100 Hz, .wav files). Sounds were recorded 24 hours a day. The recorder was placed outside on a weighted tripod or placed on the window ledge as shown in Figure 4.4. The purpose of the outdoor recordings was for identification of the noise source only; they were not calibrated recordings. In addition to the noise measurements, temperature, light, and humidity were recorded in the bedroom every one minute throughout the study (T&D Illuminance UV Recorder TR-74UI), as these environmental factors can also affect sleep. A device that detected all three environmental factors was placed on a nightstand or dresser close to the head of the bed (Figure 4.4). The placement of microphones and temperature, light, and humidity sensors was documented with photos for each study site.



Figure 4.3: Examples of the placement of the indoor microphone near the sleeping position.



Figure 4.4: An example of the position of the temperature, light and humidity sensors and outdoor sound recorder placement on a window ledge.

4.3 Subjective Assessments

Each morning participants completed a brief questionnaire on their previous night's sleep quality, noise during the night, and their level of fatigue in the morning. Subjects also completed four surveys on the first day of the study, three of which were on their sleep and health and included the Health Survey (SF-36),¹⁶ the Pittsburgh Sleep Quality Index (PSQI),¹⁷ and the Horne-Ostberg Morningness-Eveningness Questionnaire.¹⁸ The participants also completed a questionnaire with sociodemographic questions. All surveys are included in the appendix of this report. All questionnaires were implemented as web-based surveys using a system called Redcap which is designed for collecting clinical research data. The surveys were completed using Apple iPads and automatically transmitted to the Redcap server via a cellular data network upon completion.

4.4 Additional Protocol Instructions

Participants were allowed to go to sleep at their normal times and wake up at their normal times each night. Participants were asked to turn off any noise producing items such as the TV, radio, or music during the night. However, in order to preserve a regular or normal sleeping environment, participants were allowed to turn on fans, air conditioners and heaters for their comfort. Also, participants were allowed to sleep with their pets (such as dogs and cats) as they would have normally in their bedrooms. It was desired to have participants maintain as close to their normal sleep routine as possible.

4.5 Subject Recruitment

Three methods were used to recruit participants for this study. The first approach was to go door-to-door. Staff members knocked on the door of every house on a block in the evening hours between 5:00 pm and 8:30 pm for a total of 35 blocks that had the required L_{night} levels. If household members were not home, a study flyer was left hanging on the door. Flyers on the study were also placed throughout the community on public bulletin boards at locations including the post-office, library, and community centers. A total of ten participants near the airport were recruited using these two approaches.

Due to the low response, the remaining 70 participants were recruited by mailing flyers to residences. All addresses within eight census tracts were purchased from a commercial vendor. For the control region, addresses were randomly selected from the list of addresses that were obtained. For the communities near the airport, the residents with the highest predicted nighttime noise levels were selected. While the target enrollment of 80 participants was met using this approach the response rate was still low with 3,700 flyers mailed to obtain this enrollment.

Individuals interested in taking part in the study were screened over the phone to determine their eligibility. As few selection criteria as possible were used in order to increase response rates and the generalizability of results. Participants had to be 21 years or older and not be morbidly obese (BMI over 35) as the risk for sleep apnea increases with BMI. Also the participants could not have a history of cardiac arrhythmia or history of a sleep disorder (including obstructive or central sleep apnea, narcolepsy, restless legs syndrome or periodic limb movement syndrome). In addition participants had to have normal hearing, not consume sleep medication on a chronic basis, not work night shifts, or have children under five years old living in the same household. Interested individuals that were pregnant were ineligible. More than one person per household could take part in the study.

When relying on self-report for determining eligibility, there is the potential that participants have an undiagnosed condition. The heart rate and actigraphy data were examined after the 3 nights of the study to determine if the participants had either a cardiac arrhythmia or a sleep-disorder. If a condition was identified, the individual’s data was removed from analysis and a letter was sent to the participant recommending they see their medical doctor for further evaluation. In this study, only 2 participants were identified to potentially suffer from a sleep-related breathing disorder.

5. Participants and Data Overview

5.1 Participant Characteristics

Eighty participants were enrolled in the study, and 79 completed the measurements. The participants were from 56 different households. The measurements took place for 1 year with measurements starting in July 2014 and continuing through July 2015. The number of participants per month is shown in Figure 5.1.

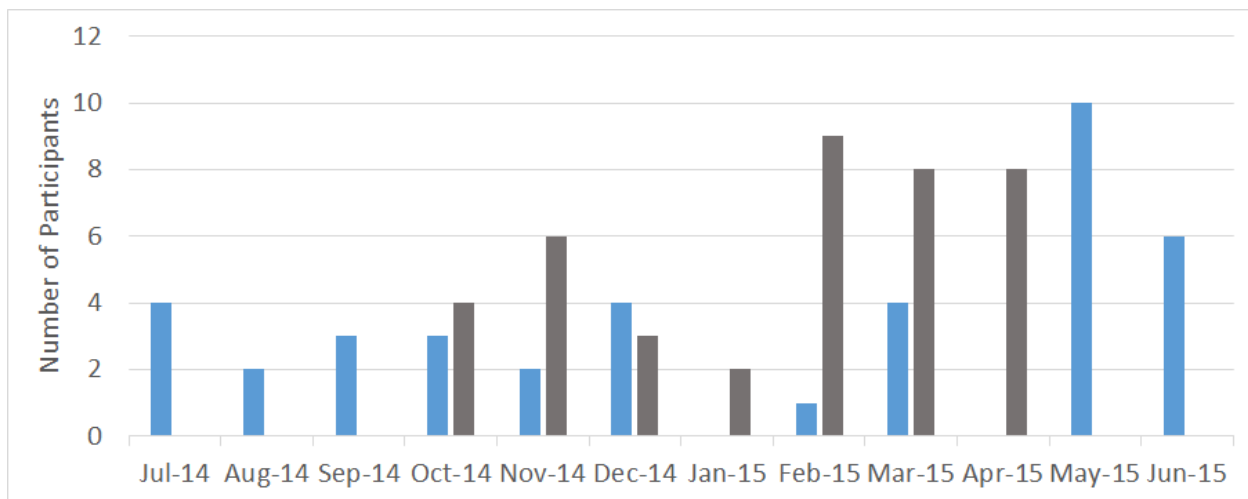


Figure 5.1: Number of participants per month. Airport noise group (blue) and control group (gray).

Demographic characteristics for the 79 participants are in Table 5.1. While the mean age of participants near the airport was higher than for the control region, participants from both areas were of a wide age range. The majority of participants in both regions had at least some college education, and the percentage of participants who considered themselves noise sensitive was low in both areas. Noise sensitive was defined as reporting very or extremely sensitive to any kind of noise on the demographic questionnaire. For all remaining analyses, data for 3 participants (1 aircraft noise exposed and 2 control region) were removed due to potential health conditions.

Table 5.1: Socio-demographic characteristics of participants in the pilot study (one subject in the aircraft noise exposed group did not start measurements).

	Aircraft Noise Exposed (N=39)	Control Region (N=40)
Age (mean, range)	46, 22-77 years	32, 22-68 years
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%
% Detached House	20.5%	12.5 %

5.2 Feasibility of Study Protocol

The primary objective of this study was to evaluate the quality of data that could be obtained by performing an unattended sleep study Table 5.2. Overall, it was found that participants were able to follow the study protocol well. For 93.4% of the nights, there were no missing periods of ECG data due to participants not wearing the device or due to improper use of the device, electrodes, or cables. For 5.7% of the nights, partial ECG recordings were obtained and for only 0.9% of nights no valid ECG data was recorded. For 93.4% of the mornings, participants completed all 3 blood pressure measurements and for 5.3% of the mornings at least one blood pressure reading was recorded. For 89.4% of the nights, full sound recordings were obtained. Data loss was due to either equipment problems or participants failing to turn on the second sound recorder at night. All questionnaires for the study were completed. The surveys were web-based which allowed staff members to verify completion of the surveys in real time and contact participants if the study protocol was not being followed. The compliance of participants in turning on the sound recorder, wearing the ECG device, and completing the morning blood pressure measurements each night/morning could not be tracked in real time.

Table 5.2: Overview of data quality

Nights of Study Completed (Total Subjects: 76)	
99.0% of subjects	Completed 3 nights/mornings
1.0% of subjects	Completed 2 of 3 nights/mornings
Heart Rate Measurements (Total Nights: 227)	
93.4% of nights	No missing recording periods due to improper use of device, electrodes, cables
5.7% of nights	Partial nights of ECG recordings
0.9% of nights	No valid ECG recording
Blood Pressure Measurements (Total mornings: 227)	
93.4% of mornings	3 of 3 blood pressure measurements completed
3.1% of mornings	2 of 3 blood pressure measurements completed
2.2% of mornings	1 of 3 blood pressure measurements completed
1.3% of mornings	0 of 3 blood pressure measurements completed
Indoor Sound Recordings (.wav files) (Total Nights: 227)	
89.4% of nights	Full recordings
7.9% of nights	Equipment problems
2.6% of nights	High background noise throughout night (e.g. TV)
Outdoor Sound Recordings (.wav files) (Total Nights: 227)	
94.7% of nights	Full recordings
2.6% of nights	No secure location to place device
2.6% of nights	Equipment problems
All questionnaires were completed	

6. Acoustic Analysis

6.1 Aircraft Event Scoring

PDARS flight operations data was obtained for the time period of the study. A Matlab (Matlab version 2014b, Mathworks) program was written in order to identify aircraft events within the nighttime noise recordings. The program calculates the distance between each aircraft's flight path and the geocoded addresses of the participants. The minimum distance between the two is determined and an aircraft event is detected in the file at the time of the minimum detected distance. All events identified by the program were also verified by a human scorer. Each sound was listened to and systematically labeled. Based on the flight operations data aircraft events were scored as either arrival or departure. The 2 minutes preceding and following each aircraft event were also scored (Figure 6.1).

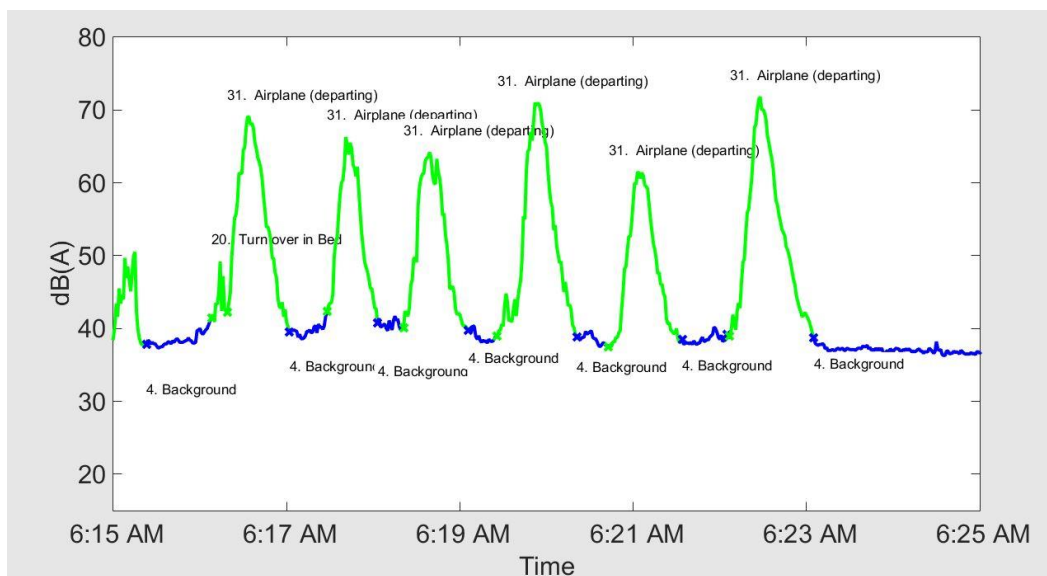


Figure 6.1: Example of clear aircraft events identified in the L_{Aeq} time histories.

If additional sounds occurred at the same time as an aircraft event (e.g. outdoor events such as a car or train, indoor events such as snoring or turning over in bed; Figure 6.2), these events were also scored. Outdoor sound recordings were used if sounds were unidentifiable using the indoor sound recordings. For 46% of participants' homes near the airport, periods of sounds were masked by high background noise levels due to heaters or air-conditioners and fans (Figure 6.3).

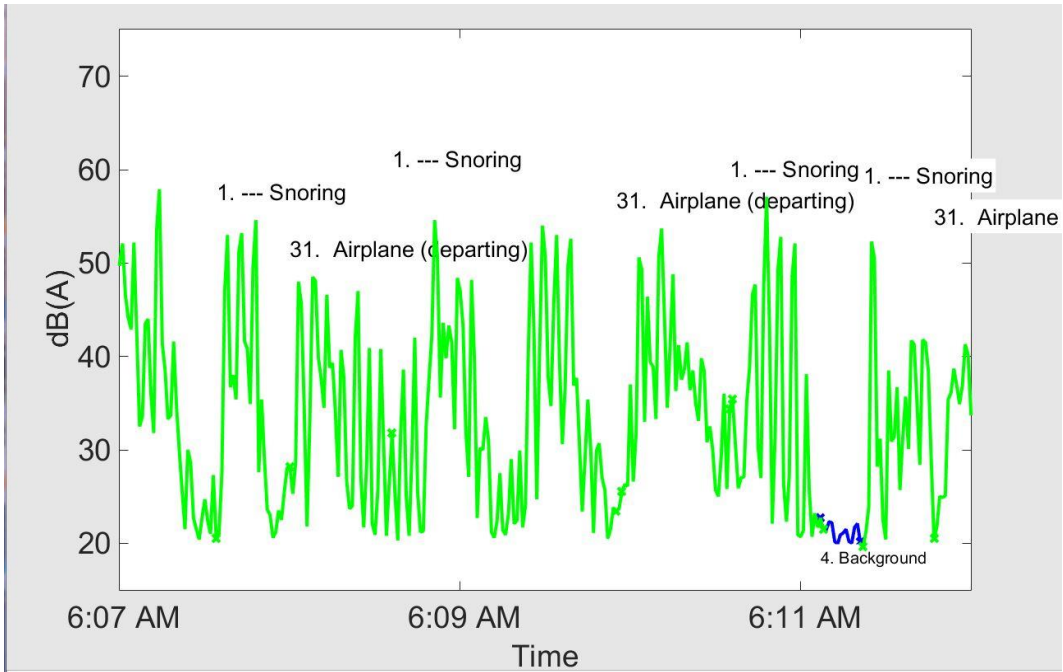


Figure 6.2: An example of data that is obscured by snoring noise

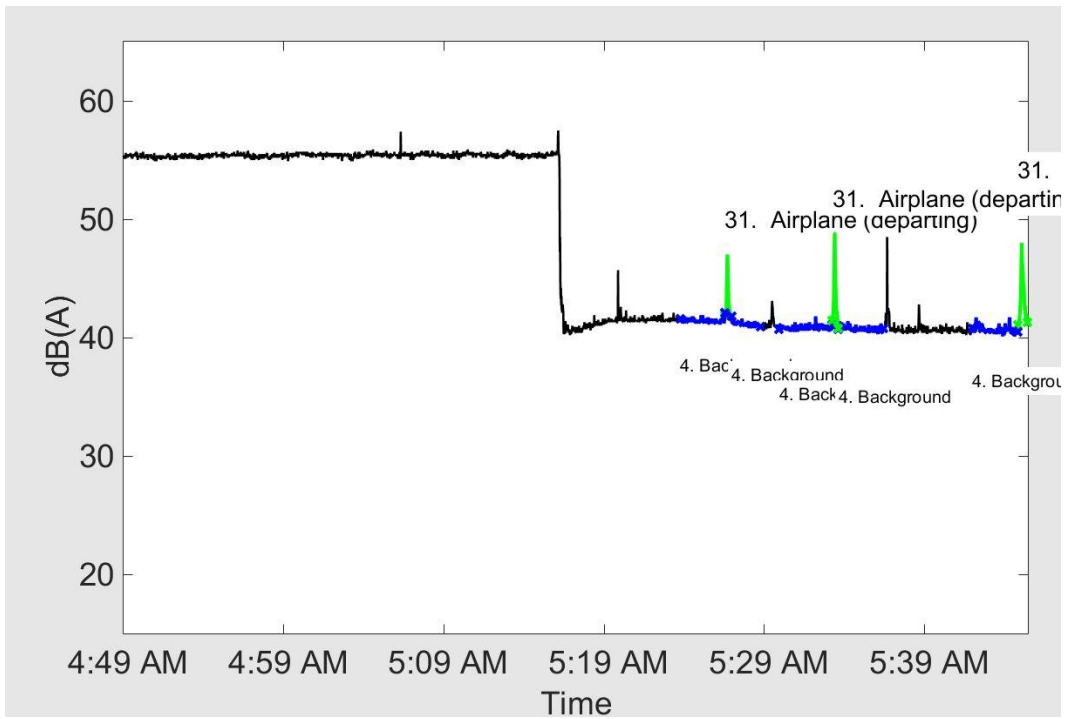


Figure 6.3: An example of high masking noise due to an air conditioner.

6.2 Aircraft Noise Levels

The distribution of indoor maximum noise levels for the aircraft events within participant's homes near the airport is shown in Figure 6.4. The total number of noise events within the sleep period for the participants near the airport was 2,375. The median indoor L_{ASmax} of the aircraft events was 45.5 dBA. The average noise level 1 minute preceding each event is also shown in Figure 6.4, and the median was 35.4 dBA. The number of events per night per subject who lived near the airport is shown in Figure 6.5. The median number of events was 65.4. Four out of the 36 participants had no audible events; this was due to masking noise from a TV, fan, or air conditioner. Twenty of the 36 subjects had greater than 60 events which was the target when the study was designed.

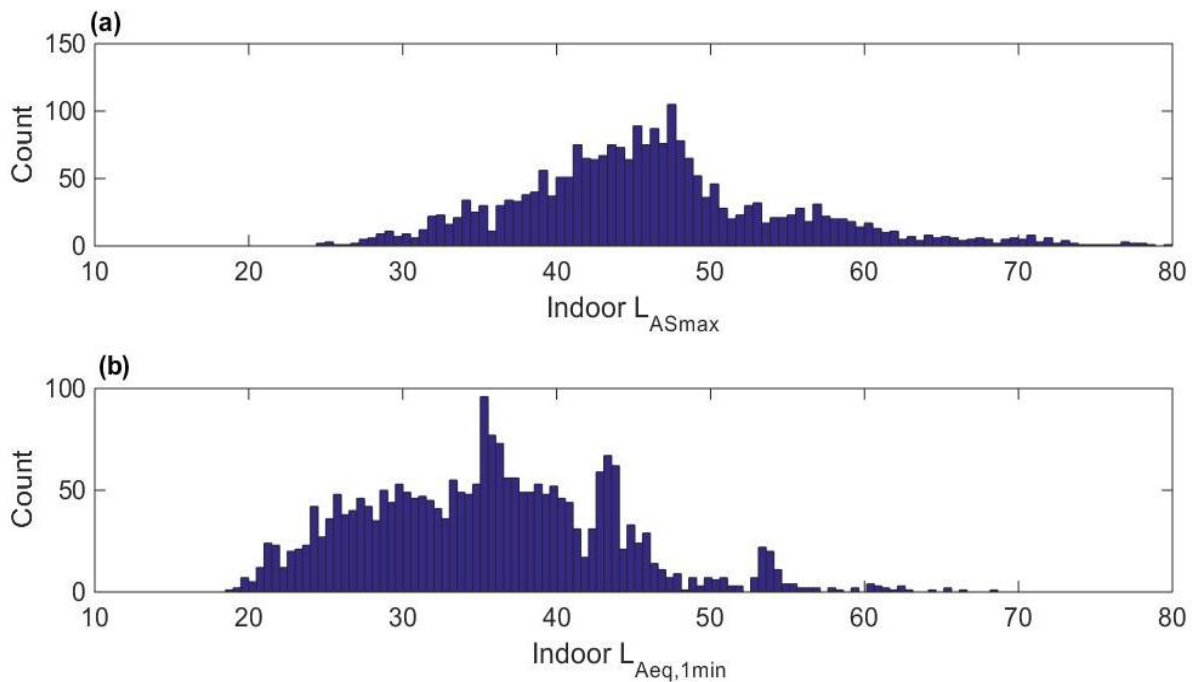


Figure 6.4: Indoor noise levels for participants near the airport. (a) L_{ASmax} of aircraft events, (b) L_{Aeq} 1 minute before each aircraft event.

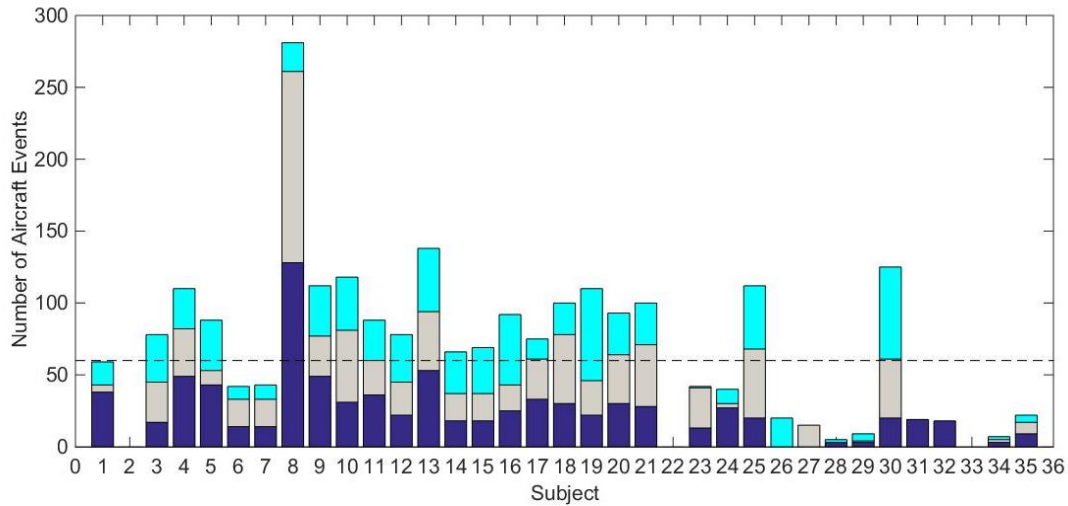


Figure 6.5: Number of events per subject near the airport for each night (4 out of the 36 participants had no audible events; this was due to masking noise from a TV, fan, or air conditioner). The colors indicate study nights.

The average indoor L_{Aeq} level for the sleep period time (SPT; the time between sleep onset and final awakening) was also calculated for each night and for both individuals living near the airport and in the control region. The median L_{Aeq} level during the sleep period time for the noise exposed group was 43.2 dBA and for the control group it was 31.8 dBA. While it was a goal of the study to have a control region completely without aircraft events, there were some overflights within the area. The median L_{ASmax} level of these events was 36 dBA. The two regions (airport and control) were similar relative to exposure to road traffic and train noise.

7. Statistical Methods

Statistical analysis was performed using SAS (version 9.3, SAS Institute, Carey, NC). For the calculation of single event exposure-response relationships for the probability of awakening, logistic mixed models with random subject intercept were calculated using Proc NLMIXED. The random intercept term accounts for the correlation of the repeated observations for each subject. In this case the repeated observations are multiple reactions to aircraft noise events observed per subject. For all other outcomes linear models were calculated using Proc Mixed.

In the models, the variables of noise level, age, BMI and time from sleep onset were included as continuous variables. Gender (value of 1=male, 0=female) and study region (value of 1=airport region, 0=control region) were included as indicator variables. The coefficient estimates for the variables in the models are reported. A p-value of 0.05 or less was considered statistically significant.

8. Heart Rate and Actigraphy Analysis

8.1 Heart Rate and Actigraphy Awakening Identification Program

Awakenings during the night were identified automatically based on the heart rate and actigraphy data. The software is based on the algorithm of Basner et al. (2007) which identified EEG arousals (≥ 3 seconds) based on heart rate alone. This algorithm was refined to identify EEG awakenings (≥ 15 seconds) using heart rate and actigraphy data, which is a more specific indicator of noise-induced sleep disturbance due to the lower frequency of occurrence on nights without noise exposure. Awakenings are identified in the algorithm by using matrices of likelihood ratios which indicate whether the difference in the beat to beat heart rate to a 3 minute median heart rate or the amount of movement is associated with an awakening.

Awakenings were calculated for every subject night. After the calculations were completed, artifacts in the heart rate signals were visually identified, and these periods were removed from analysis. During periods in which the heart rate signal was invalid (6% of nights had invalid periods), awakenings were identified based on actigraphically determined movement only and included in the analysis. The accuracy of detecting awakenings based on actigraphy alone is somewhat lower relative to heart rate alone or heart rate and actigraphy combined. However, the agreement with polysomnography was still found to be almost perfect ($\kappa = 0.81$; compared to $\kappa = 0.87$ for actigraphy and heart rate combined).

The Faros devices had a time drift of up to 10 seconds over the 4 days. This was determined based on time synchronizations of the devices before and after each set of measurements. In comparison, the Larsen and Davis 831 Sound Level Meter had a stable time and only drifted on average 1 second over the 4-day period. To correct for the time drift time between the two devices, the difference in the onset of movement detected in the actigraphy signal and detected audibly in the sound recordings was determined for at least 3 time points per night. The time of the awakenings was then corrected linearly. This time drift correction was necessary for the single event awakening analysis.

8.2 Descriptive Sleep Parameters of the Entire Night

The cumulative distribution of the sleep period times calculated based on the heart rate and actigraphy data for all participants is shown in Figure 8.1. The majority of participants were asleep between 23:00 and 7:00. The median sleep period time was 7.5 hours.

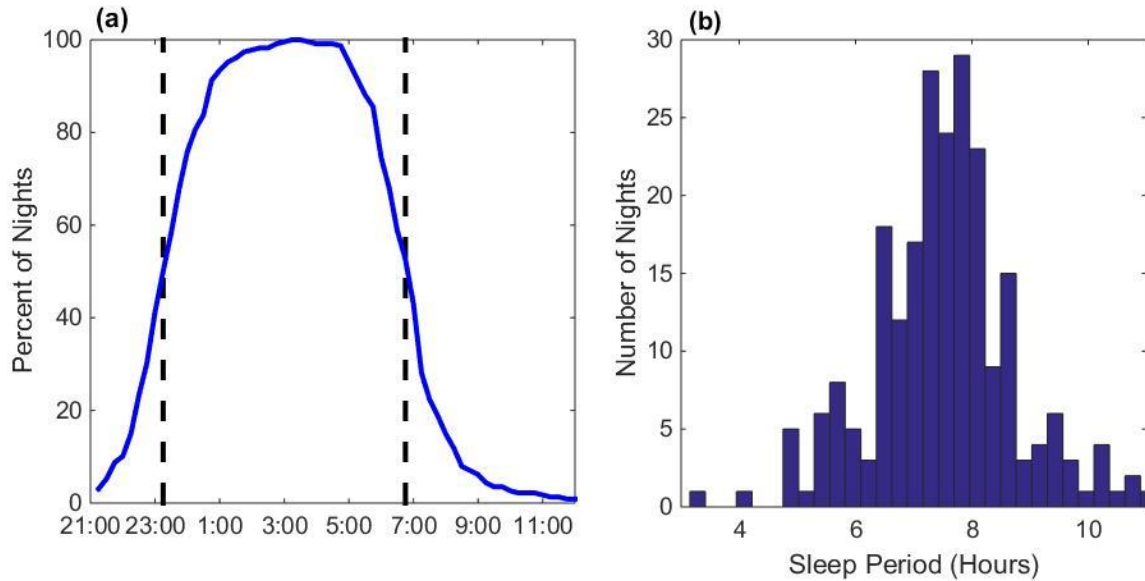


Figure 8.1: (a) Percentage of sleeping participants, and (b) distribution of sleep period durations for all nights ($N=227$ nights).

The sleep fragmentation index was also calculated for each night. This index is defined as the number of awakenings divided by the sleep period time in hours. Mixed models with random subject intercept were calculated and the results are shown in Table 8.1. Model 1 was adjusted for age, gender, BMI, and study region. Model 2 contained the average noise level during the sleep period (L_{Aeq}) instead of the region. In both models the only variable that was significant was age, which was negatively associated with the sleep fragmentation index. We also added a term for age^2 to determine whether there was a non-linear trend with age, but no significant effect was observed ($p = 0.8037$ in Model 1 and $p=0.8912$ in Model 2 for age^2).

Table 8.1: Mixed model results for the Sleep Fragmentation Index

	Model 1			Model 2		
	Estimate	Standard Error	p-value	Estimate	Standard Error	p-value
Age	-0.0363	0.0160	0.0260	-0.0358	0.0160	0.0285
Male	0.5205	0.4234	0.2230	0.6816	0.4280	0.1160
BMI	-0.0057	0.0537	0.9158	0.0153	0.0543	0.7791
Airport	0.1850	0.4760	0.6986			
L_{Aeq} [dB]				0.0036	0.0242	0.8809

8.3 Single Event Awakening Analysis

All aircraft events were included in the single event analysis regardless of whether another noise source occurred at the same time, such as an aircraft event occurring at the same time as a car pass-by. In analyses performed for WHO based on data from DLR’s STRAIN study, it was found that for aircraft noise, exposure-response relationships did not vary relevantly when including all events or only events that did not co-occur with noise events from other sources. Identical to the STRAIN and NORAH field studies on the effects of aircraft noise on sleep, a 90-second time window was screened for an awakening after the start of an aircraft noise event, and no awakening reaction could occur within 15 seconds prior to the start of the aircraft noise event to be included in the analysis.

Random intercept logistic regression models were calculated for the probability of awakening to an aircraft. Model 1 contained only the indoor maximum noise level, Model 2 was adjusted for age, gender and time from sleep onset (Table 8.2). In both models the coefficient for L_{ASmax} was positive and significant (i.e., awakening probability increased statistically significantly with increasing L_{ASmax}). In Model 2 the probability of awakening was found to increase significantly with the time from sleep onset, consistent with previous findings.²

Table 8.2: Random effect logistic regression models for the probability of awakening

	Model 1			Model 2		
	Estimate	Standard Error	p-value	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

The spontaneous awakening probability (i.e., the probability of awakenings during noise-free periods) was also calculated by screening a period of 90 seconds from the start of virtual events for awakening reactions. Virtual events (i.e., periods of identical duration as the aircraft noise events but without aircraft noise) were assigned randomly to time periods within 30 minutes of an aircraft event within the other two nights of the same subject. As the time of the virtual events was chosen randomly, the calculations were repeated 100 times. The mean unadjusted spontaneous awakening probability was 12.2%.

The exposure-response relationship for additional awakenings due to aircraft events ($P_{\text{noise}} - P_{\text{spontaneous}}$) is shown in Figure 8.2 (this relationship is based on the unadjusted Model 1 above). Also in the figure are exposure-response curves calculated based on ECG and actigraphy data for the STRAIN study and the 3 years of the NORAH sleep study. The STRAIN and NORAH studies were conducted by the German Aerospace Center around Cologne-Bonn Airport and Frankfurt Airport, respectively. The STRAIN study was conducted between September 2001 and November 2002, and had 64 participants (average age 38 years, 44% male). Subjects participated for nine consecutive nights. The NORAH study was conducted between July 2011 and November 2013. There were 49 participants in 2011 (average age 41 years, 49% Male), 83 in 2012 (average age 43 years, 41% Male), and 187 in 2013 (average age 40 years, 43% Male). The NORAH study in 2011 was conducted before a ban on nighttime flights between 23:00-5:00, and the studies in 2012 and 2013 were conducted after the ban. The STRAIN study and NORAH 2011 and 2012 studies used polysomnography (which includes the ECG) to measure sleep. In NORAH 2013 a similar unattended methodology of using ECG and actigraphy to monitor sleep, as in the PHL study, was used.

The exposure-response relationship calculated for the PHL study has a non-zero probability of awakening starting at 34 dBA and increases to an awakening probability of over 10% for events with a maximum noise level of 70 dBA. The onset of additional awakenings is

consistent across the 3 studies. It varied from 30 dBA in the STRAIN study to 36 dBA in the NORAH study. The increase in awakening probability with the indoor maximum noise level is also comparable across all studies. Due to the relatively low number of subjects and aircraft noise events per subject, the 95% confidence interval of the PHL exposure-response function is relatively wide, indicating the higher uncertainty compared to the other field studies, especially the STRAIN study.

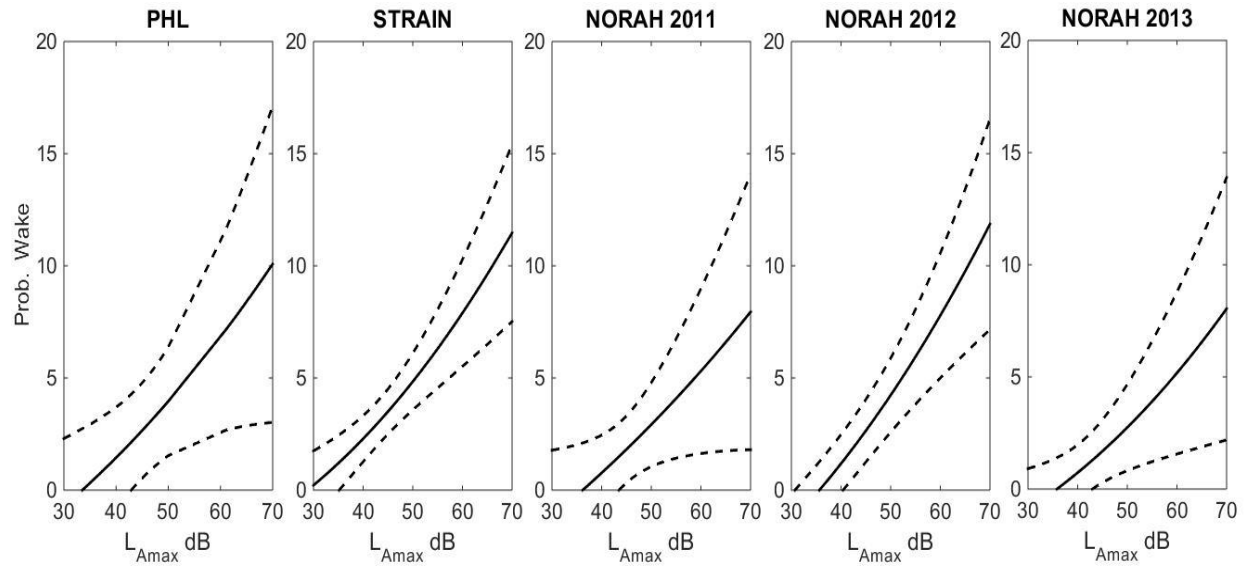


Figure 8.2: The unadjusted probability of an additional awakening within a 90 second time window from the start of an aircraft event, for the Philadelphia Airport pilot study (PHL) and the STRAIN and NORAH studies conducted by the German Aerospace Center. Dotted lines are the 95% confidence intervals.

9. Blood Pressure Measurement Analysis

The systolic and diastolic blood pressure levels were averaged across all 3 measurements for each morning. Mixed models with a random subject intercept were calculated and adjusted for age, gender, BMI, and study region.

Systolic blood pressure increased significantly with age ($p < 0.0001$), BMI ($p = 0.0159$) and was higher in male participants ($p < 0.0001$). No statistically significant association was found for region ($p = 0.3255$). For diastolic blood pressure, there was a statistically significant association with BMI ($p = 0.0011$) and age ($p = 0.0009$), but not gender ($p = 0.0896$). No statistically significant association was found for the region ($p = 0.7108$).

10. Self-Reported Results

10.1 PROMIS Sleep Questions

In our sociodemographic questionnaire we asked several questions on sleep that were based on the PROMIS Sleep Questionnaire.¹⁹ The participants were asked several questions about their sleep quality during the past month which are listed in Table 10.1. Each question had a 5 point response scale which ranged from never (1) to always (5). Linear mixed effect models adjusted for age, gender, BMI, and study region were calculated. The coefficients for airport region are in Table 10.1. Several results were statistically significant with participants near the airport reporting their sleep as less refreshing ($p=0.0255$), they had more difficulty falling asleep ($p=0.0267$), and did not get enough sleep ($p=0.0235$) compared to those living in the control region.

Table 10.1: Coefficient for airport region based on linear mixed models adjusted for age, gender, and BMI for the listed sleep questions. Response categories were always (5), often (4), sometimes (3), rarely (2), and never (1).

	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

10.2 SF-36 Health Survey

The SF-36 survey contains several questions to evaluate an individual's perceived health. Linear mixed models were calculated for several questions, and were adjusted for age, gender, and BMI, and study region. When participants were asked to rate their health from poor (1) to excellent (5), those living in the airport region tended to rate their health worse than those living in the control region, albeit statistically non-significantly (-0.4122 , $p=0.0538$). The coefficient for the airport region for several questions in which participants were asked to rate how true or false the statements were can be found in Table 10.2. Participants living near the airport rated that they expected their health to get worse ($+0.60$, $p=0.0308$) and that their health was not excellent (-0.58 , $p=0.0074$) compared to the control region.

Table 10.2: Coefficient for airport region for linear mixed models adjusted for age, gender, and BMI for the listed health questions. Response categories were (5) Definitely true, (4) Mostly true, (3) Don't know, (2) Mostly false, and (1) Definitely false.

	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

10.3 Pittsburgh Sleep Quality Index (PSQI)

The PSQI was filled out once on the first day of the study. It retrospectively assesses sleep quality over a period of a month. Responses to individual questions on the PSQI survey were combined to obtain a global score, which ranges from 0 (indicating best sleep quality) to 21 (indicating worst sleep quality). Scores > 5 are typically used to distinguish poor quality sleep from high quality sleep. Linear mixed models adjusted for age, gender, BMI, and study region were calculated for the global score. Those living near the airport (mean PSQI 6.2, SD 2.9) had a significantly higher global PSQI score indicating worse sleep quality compared to the control region (mean PSQI 4.4, SD 1.8). 60.5% in the airport region reported a PSQI score > 5 compared to 18.4% in the control region (p=0.0061). Higher BMI was also significantly related to worse subjective sleep quality (p=0.0420), while age and gender showed no statistically significant relationship (p>0.05).

Table 10.3: Coefficients for linear mixed models adjusted for age, gender, and BMI for the global PSQI score.

	Estimate	Standard Error	p-value
Age	0.0094	0.0211	0.6573
Male	-0.4071	0.5600	0.4697
BMI	0.1473	0.0711	0.0420
Airport	1.5227	0.6287	0.0180

10.4 Morning Survey

The morning survey was completed on every study morning (i.e., 3 measurements per subject) and contained questions on sleep quality and fatigue. Linear mixed models, adjusted for age, gender, BMI, and study region were calculated to determine whether there was a difference in evaluations between the control and airport noise exposed region. Participants near the airport rated they were more tired (coefficient estimate for airport region: 0.4598). However, this did not differ significantly between the airport and the control region ($p=0.3481$). There was also no statistically significant difference between regions for ratings of difficulty falling asleep ($p=0.9724$) and sleep quality ($p=0.3231$). Furthermore, no association was found between average noise levels during the sleep period and difficulty falling asleep ($p=0.7146$) or sleep quality ($p=0.4517$).

11. Discussion

The primary objective of this pilot field study was to evaluate feasibility, and more specifically the quantity and quality of the data that could be obtained when sleep and noise measurements were completed unattended. For all measurements, there was less than 10% of data loss. Participants were able to correctly apply the electrodes and use the heart rate and actigraphy device. The primary reason for data loss was cables coming off the electrodes. However, actigraphy data was obtained in all cases. Additionally, participants turned on the sound recorder for the majority of nights. Overall, this demonstrates feasibility of unattended physiological and noise measurements.

The second objective of this study was to evaluate whether there were differences in objective and subjective sleep and health measures between the control region and the region by the airport. No significant difference was found for the sleep fragmentation index between sites. This is somewhat surprising, especially since a significant exposure-response relationship between aircraft noise L_{ASmax} and awakenings inferred from body movements and ECG arousals was found (see below). It is possible that airport residents were able to compensate for noise-induced awakenings during noise-free intervals.²⁰ Furthermore, the ECG-based algorithm is somewhat less sensitive in older subjects, and even though we adjusted for age in our models, residual confounding may have masked a higher sleep fragmentation in airport residents.

Those living near the airport did not have a higher diastolic or systolic blood pressure in the morning. For subjective responses, it was found that those living near the airport reported poorer sleep quality reflected in responses to the PROMIS and PSQI sleep questions, and poorer health as reported in the SF-36. It is currently unclear whether additional confounding variables that were

not collected in the current study may account for these differences. The extension of this pilot study currently underway at a different US airport collects more extensive information on noise exposure, attitudes, and health outcomes, and also investigates a much larger sample (up to 1,000 surveys and up to 200 subjects across 5 study nights), and will thus likely shed more light on this open question. The PROMIS and PSQI sleep questions referred to a 1-month time frame. When participants were asked about their sleep the preceding night in the morning surveys, no significant difference was found between the airport and the control group.

An exposure-response model relating the indoor noise level of the aircraft events to the probability of awakening inferred from body movements and ECG arousals was also derived. Awakening probability increased statistically significantly with L_{ASmax} of aircraft noise events both in the unadjusted model and in the model adjusted for age, gender, and elapsed sleep time. The number of aircraft events in this study of high noise levels was low, as shown by the skewed distribution of noise levels. In addition, the total number of aircraft events contributing to this analysis was only approximately 2,000. These two limitations led to a wide confidence interval for the estimated awakening probability. However, the noise level at which there was a nonzero probability of additional awakenings (i.e., awakening threshold) and the increase in probability of awakenings with the indoor maximum noise level was consistent with the findings of the STRAIN study and 3 years of the NORAH study, which supports the findings of this study.

12. Outlook

The long-term goal of this line of research is to derive exposure-response relationships that are representative for the US population exposed by nocturnal aircraft noise. This study was the first step in evaluating the feasibility of a study methodology for collecting unattended physiological and noise data to develop these models. Based on experiences in this study, further refinements of the protocol are needed:

The target enrollment of 80 participants for the study was met. However, to recruit the participants, 3,700 flyers were mailed. This low response rate limits the generalizability of the results. One contributing factor to the low response rate may be that, while the measurements took place unattended, staff members still had to enter participants' homes to setup and collect the equipment. A website was created with information on the study which allowed individuals to verify both the study and study team. The link for the website was provided on the recruitment flyers. However, despite the website and the provided information, potential participants may still have been reluctant to allow unknown individuals into their home.

Another limitation of the study design was the methodological expense. This study required staff to be in the field from 2 to 4 days per week. If a multi-airport field study was conducted this way, trained staff would be required close to each of the measurement sites, which may not be feasible. In addition, the sound recording equipment used for this study costs several thousand dollars, which restricts the number of devices that can be purchased or available for use, restricts the number of sites that can be studied concurrently, and thus also limits the sample size for the study. For this study, we had equipment to study three sites concurrently, which meant a minimum of 27 weeks of field work.

Finally, visual identification of aircraft noise and other events was cumbersome and also requires trained staff. We made important progress in automatically identifying aircraft noise events based on sound level measurements and flight-track data. However, aircraft noise events were often masked by other indoor noise sources, especially air conditioning units. In the current project year, we hope to develop a methodology that allows estimating maximum sound pressure levels of masked aircraft noise events inside the bedroom based on outdoor noise predictions and a relationship established based on these predictions and unmasked aircraft noise events.

In an extension of the pilot field study discussed here, we have modified the study design. Inexpensive yet reliable equipment for physiological and acoustical measurements will be mailed out to participants, who will then set up, use, and mail back the equipment without the need of trained investigators on site. In addition to lower expenses and higher sample sizes, we hope that participation rates will increase substantially, as no investigator will be intruding into the homes of participants. If this methodological approach proves feasible, it would allow high-quality yet cost effective measurements of large subject samples around multiple US airports that are needed to inform policies to protect airport residents from potential adverse effects of nocturnal aircraft noise exposure.

13. Acknowledgements

This work was funded by the U.S. Federal Aviation Administration (FAA) Office of Environment and Energy as a part of ASCENT Project 17 under FAA Award Numbers: 13-C-AJFE-UPENN-001 and 13-C-AJFE-UPENN-002. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the FAA or other ASCENT Sponsors. We would like to thank our project manager Natalia Sizov (FAA) for her support of the study. We would like to thank the Volpe Transportation Systems center who provided the indoor sound recording equipment used in this study. Finally, we would like to thank Uwe Müller, Daniel Aeschbach, Eva-Maria Elmenhorst,

and Franco Mendolia of the Flight Physiology Division, Institute for Aerospace Medicine, German Aerospace Center (DLR). The FAA engaged in a cooperative agreement with DLR, and the ECG and actigraphy methodology was jointly refined with colleagues from DLR.

14. References

1. Rechtschaffen A, Kales A, Berger RJ, et al. A manual of standardized terminology, techniques and scoring system for sleep stages of human subjects. Washington, D.C.: Public Health Service, U.S. Government, Printing Office, 1968.
2. Iber C, Ancoli-Israel S, Chesson A, Quan SF. The AASM manual for the scoring of sleep and associated events: rules, terminology and technical specifications. Westchester, Illinois: American Academy of Sleep Medicine; 2007.
3. Aasvang GM, Overland B, Ursin R, Moum T. A field study of effects of road traffic and railway noise on polysomnographic sleep parameters. *The Journal of the Acoustical Society of America* 2011; 129(6): 3716-26.
4. Basner M, Isermann U, Samel A. Aircraft noise effects on sleep: Application of the results of a large polysomnographic field study. *The Journal of the Acoustical Society of America* 2006; 119(5): 2772-84.
5. Elmenhorst EM, Pennig S, Rolny V, et al. Examining nocturnal railway noise and aircraft noise in the field: sleep, psychomotor performance, and annoyance. *Science of the Total Environment* 2012; 424: 48-56.
6. Flindell IH, Bullmore AJ, Robertson KA, et al. Aircraft noise and sleep, 1999 UK trial methodology study. University of Southampton, UK: ISVR Consultancy Services, Institute of Sound and Vibration Research, 2000.
7. Danker-Hopfe H, Anderer P, Zeitlhofer J, et al. Interrater reliability for sleep scoring according to the Rechtschaffen & Kales and the new AASM standard. *Journal of Sleep Research* 2009; 18(1):74-84.
8. Basner M, Griefahn B, Penzel T. Inter-rater agreement in sleep stage classification between centers with different backgrounds. *Somnologie* 2008; 12(1):75-84.
9. Agnew H, Webb W, Williams R. The first night effect: An EEG study of sleep. *Psychophysiology* 1966; 2: 263-6.
10. Jean-Louis G, Kripke DF, Mason WJ, et al. Sleep estimation from wrist movement quantified by different actigraphic modalities. *Journal of Neuroscience Methods* 2001; 105(2): 185-191.
11. Basner M, Griefahn B, Müller U et al. An ECG-based algorithm for the automatic identification of autonomic activations associated with cortical arousal. *Sleep* 2007; 30(10):1349-1361.
12. Bonnet, MH. EEG arousal norms by age. *Journal of Clinical Sleep Medicine* 2007; 3(3): 271-4.

13. McGuire S, Müller U, Plath G, and Basner M. Refinement and validation of an ECG based algorithm for detecting awakenings. Proceedings of the 11th International Congress on Noise as a Public Health Problem (ICBEN), Nara, Japan, 2014.
14. Basner M, Brink M, Elmenhorst E-M. Critical appraisal of methods for the assessment of noise effects on sleep. *Noise & Health* 2012; 14(61): 321-329.
15. Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics* 1977; 33(1):159-174.
16. Ware JE, Sherbourne CD. The MOS 36-item short-form health survey (SF-36). 1. Conceptual framework and item selection. *Medical Care* 1992; 30(6): 473-83.
17. Buysse DJ, Reynolds CF, 3rd, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh Sleep Quality Index: A new instrument for psychiatric practice and research. *Psychiatry Research* 1989; 28(2): 193-213.
18. Horne JA, Ostberg O. A self-assessment questionnaire to determine morningness-eveningness in human circadian rhythms. *International Journal of Chronobiology* 1976; 4(2): 97-110.
19. Yu L, Buysse DJ, Germain A et al. Development of short forms from the PROMIS sleep disturbance and sleep-related impairment item banks. *Behavioral Sleep Medicine* 2011; 10(1):6-24.
20. Basner M, Müller U, Elmenhorst E-M. Single and combined effects of air, road, and rail traffic noise on sleep and recuperation. *Sleep* 2011; 34(1):11-23.

15. Appendix

15.1 Mailed Recruitment Flyer



Penn Medicine

Perelman School of Medicine at the University of Pennsylvania

**Division of Sleep and Chronobiology
Department of Psychiatry**

Mathias Basner, MD, PhD, MSc

Assistant Professor of Sleep and Chronobiology in Psychiatry

Community Noise & Sleep Study

The University of Pennsylvania is recruiting individuals in your neighborhood to take part in a research study to:

Understand How Noise in Your Community Affects Sleep

The study is a 3 night, in-home, unattended sleep study.

The study includes the following measurements:

- Outdoor and indoor sound recordings.
- Measurement of body movement and heart rate at night using small, noninvasive devices.
- Blood pressure measurements in the morning using a home monitor.
- Completion of surveys on your health, sleep, and noise.

During the study you can go to sleep and wake up at your normal times. During the day and evening you can go about your normal activities.

If you are 21 or older, have no known sleep disorders, and have normal hearing you may be eligible to take part in this study. More than 1 person per household can take part.

Compensation is \$50.00 per night per subject.

Additional information on the study can be found at:

Website: http://www.med.upenn.edu/uep/projects_pcns.html

If you are interested in participating:

Call: Sarah McGuire at 215-898-0474 (8:00 AM to 5:00 PM)

Email: noise@mail.med.upenn.edu

We look forward to hearing from you soon!


15.2 Screening Survey

Screening Survey		Resize font: + -
		Page 1 of 3
Was the screening completed <small>* must provide value</small>	<input type="radio"/> Over the phone <input type="radio"/> In the field	reset
Subject ID <small>* must provide value</small>	<input type="text"/>	
1. How old are you? <small>* must provide value</small>	<input type="text"/>	
2. Observe: Gender <small>* must provide value</small>	<input type="radio"/> Female <input type="radio"/> Male	reset
4. How much do you weigh? <small>* must provide value</small>	<input type="text"/> lbs	
5. How tall are you? <small>* must provide value</small>	<input type="text"/> feet	
<small>* must provide value</small>	<input type="text"/> inches	
6. BMI	<input type="text"/>	

7.	Are you able to read and write in English? <small>* must provide value</small>	<input type="radio"/> Yes <input type="radio"/> No	reset
8.	Are there any children in the household under the age of 5? <small>* must provide value</small>	<input type="radio"/> Yes <input type="radio"/> No	reset
9.	Do you currently work night shifts? <small>* must provide value</small>	<input type="radio"/> Yes <input type="radio"/> No	reset
10.	Do you have a cardiac arrhythmia? <small>* must provide value</small>	<input type="radio"/> Yes <input type="radio"/> No	reset
11.	Do you use hearing aids? <small>* must provide value</small>	<input type="radio"/> Yes <input type="radio"/> No	reset
12.	To the best of your knowledge do you have normal hearing? <small>* must provide value</small>	<input type="radio"/> Yes <input type="radio"/> No	reset
13.	Do you wear earplugs at night? <small>* must provide value</small>	<input type="radio"/> Yes <input type="radio"/> No	reset
14.	During the <u>past month</u> , how often have you taken medicine, prescribed or over-the-counter, to help you sleep including melatonin? <small>* must provide value</small>	<input type="radio"/> 2 times/week or less <input type="radio"/> more than 2 times/week	reset

15. Have you ever been diagnosed by a doctor or other health professional with..			
	Yes	No	
(a) Sleep apnea? <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	reset
(b) Narcolepsy? <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	reset
(c) Restless leg syndrome? <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	reset
(d) Periodic limb movement syndrome? <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	reset
(e) Other sleep disorder? <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	reset

15.3 PSQI Survey

PSQI Survey Resize font: 

Please complete the survey below.

Page 1 of 5

Subject ID:
* must provide value

The following questions relate to your usual sleep habits during the past month only. Your answers should indicate the most accurate reply for the majority of days and nights in the past month. Please answer all questions.

1.	During the past month, when have you usually gone to bed at night? <small>* must provide value</small>	<input type="text"/> Usual Bed Time
2.	During the past month, how long (in minutes) has it usually taken you to fall asleep each night? <small>* must provide value</small>	<input type="text"/> Number of Minutes
3.	During the past month, when have you usually gotten up in the morning? <small>* must provide value</small>	<input type="text"/> Usually Getting Up Time
4.	During the past month, how many hours of actual sleep did you get at night? (This may be different than the number of hours you spent in bed) <small>* must provide value</small>	<input type="text"/> Hours of Sleep Per Night

5. During the past month, how often have you had trouble sleeping because you...

		Not during the past month	Less than once a week	Once or twice a week	Three or more times a week	
(a)	Cannot get to sleep within 30 minutes <i>* must provide value</i>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset
(b)	Wake up in the middle of the night or early morning <i>* must provide value</i>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset
(c)	Have to get up to use the bathroom <i>* must provide value</i>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset
(d)	Cannot breathe comfortably <i>* must provide value</i>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset
(e)	Cough or snore loudly <i>* must provide value</i>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset
(f)	Feel too cold <i>* must provide value</i>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset
(g)	Feel too hot <i>* must provide value</i>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset
(h)	Had bad dreams <i>* must provide value</i>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset
(i)	Have pain <i>* must provide value</i>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset
(j)	Other reason(s) <i>* must provide value</i>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset

6. **During the past month, how would you rate your sleep quality overall?**
 * must provide value

Very good
 Fairly good
 Fairly bad
 Very bad

reset

7. **During the past month, how often have you taken medicine (prescribed or "over the counter") to help you sleep?**
 * must provide value

Not during the past month
 Less than once a week
 Once or twice a week
 Three or more times a week

reset

8. **During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?**
 * must provide value

Not during the past month
 Less than once a week
 Once or twice a week
 Three or more times a week

reset

9. **During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?**
 * must provide value

No problem at all
 Only a very slight problem
 Somewhat of a problem
 A very big problem

reset

10. **Do you have a bed partner or roommate?**
 * must provide value


No bed partner or roommate
 Partner/roommate in other room
 Partner in same room, but not same bed
 Partner in same bed

reset

11. If you have a roommate or bed partner, ask him/her how often in the past month you have had...

		Not during the past month	Less than once a week	Once or twice a week	Three or more times a week
(a)	Loud snoring * must provide value	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
(b)	Long pauses between breaths while asleep * must provide value	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
(c)	Legs twitching or jerking while you sleep * must provide value	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
(d)	Episodes of disorientation or confusion during sleep * must provide value	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
(e)	Other restlessness while you sleep * must provide value	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

15.4 SF-36 Survey

SF36 Health Survey Resize font: 

Please answer every question. Some questions may look like others, but each one is different.

Page 1 of 8

Subject ID:
* must provide value

1. In general, would you say your health is:
* must provide value

Excellent Very Good Good Fair Poor reset

2. Compared to one year ago, how would you rate your health in general now?
* must provide value

Much better now than one year ago
 Somewhat better now than one year ago
 About the same as one year ago
 Somewhat worse now than one year ago
 Much worse now than one year ago reset

3. The following items are about activities you might do during a typical day. Does your health now limit you in these activities? If so, how much?

		Yes, limited a lot	Yes, limited a little	No, not limited at all	
a.)	Vigorous activities, such as running, lifting heavy objects, participating in strenuous sports <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset
b.)	Moderate activities, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset
c.)	Lifting or carrying groceries <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset
d.)	Climbing several flights of stairs <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset
e.)	Climbing one flight of stairs <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset
f.)	Bending, kneeling, or stooping <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset
g.)	Walking more than a mile <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset
h.)	Walking several blocks <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset
i.)	Walking one block <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset
j.)	Bathing or dressing yourself <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset

4. During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of your physical health?

		Yes	No	
a.)	Cut down on the amount of time you spent on work or other activities <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	reset
b.)	Accomplished less than you would like <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	reset
c.)	Were limited in the kind of work or other activities <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	reset
d.)	Had difficulty performing the work or other activities (for example, it took extra time) <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	reset

5. During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of any emotional problems (such as feeling depressed or anxious)?

	Yes	No	
a.) Cut down on the amount of time you spent on work or other activities <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	reset
b.) Accomplished less than you would like <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	reset
c.) Didn't do work or other activities as carefully as usual <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	reset

6. During the past 4 weeks, to what extent has your physical health or emotional problems interfered with your normal social activities with family, friends, neighbors, or groups?

* must provide value

- Not at all Slightly Moderately Quite a bit Extremely

reset

7. How much bodily pain have you had during the past 4 weeks?

* must provide value

- None Very mild Mild Moderate Severe Very severe

reset

8. During the past 4 weeks, how much did pain interfere with your normal work (including both work outside the home and housework)?

* must provide value

- Not at all A little bit Moderately Quite a bit Extremely

reset

9. These questions are about how you feel and how things have been with you during the past 4 weeks. For each question, please give the one answer that comes closest to the way you have been feeling. How much of the time during the past 4 weeks...

		All of the time	Most of the time	A good bit of the time	Some of the time	A little of the time	None of the time	
a.)	did you feel full of pep? <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset
b.)	have you been a very nervous person? <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset
c.)	have you felt so down in the dumps nothing could cheer you up? <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset
d.)	have you felt calm and peaceful? <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset
e.)	did you have a lot of energy? <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset
f.)	have you felt downhearted and blue? <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset
g.)	did you feel worn out? <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset
h.)	have you been a happy person? <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset
i.)	did you feel tired? <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset

10. During the past 4 weeks, how much of the time has your physical health or emotional problems interfered with your social activities (like visiting friends, relatives, etc.)?
* must provide value

All of the time
 Most of the time
 Some of the time
 A little of the time
 None of the time

reset

11. How TRUE or FALSE is each of the following statements for you?

		Definitely true	Mostly true	Don't know	Mostly false	Definitely false	
a.)	I seem to get sick a little easier than other people <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset
b.)	I am as healthy as anybody I know <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset
c.)	I expect my health to get worse <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset
d.)	My health is excellent <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset

15.5 Morningness-Eveningness Survey

MEQ Survey

Resize font:



Please complete the survey below.

Subject ID: <small>* must provide value</small>	<input type="text"/>
1. Considering only your own "feeling best" rhythm, at what time would you get up if you were entirely free to plan your day? <small>* must provide value</small>	<p><input type="radio"/> 5:00-6:30 AM <input type="radio"/> 6:30-7:45 AM <input type="radio"/> 7:45-9:45 AM <input type="radio"/> 9:45-11:00 AM <input type="radio"/> 11:00 AM-12:00 (noon)</p> <p>reset</p>
2. Considering only your own "feeling best" rhythm, at what time would you go to bed if you were entirely free to plan your evening? <small>* must provide value</small>	<p><input type="radio"/> 8:00-9:00 PM <input type="radio"/> 9:00-10:15 PM <input type="radio"/> 10:15 PM-12:30 AM <input type="radio"/> 12:30-1:45 AM <input type="radio"/> 1:45-3:00 AM</p> <p>reset</p>
3. If there is a specific time at which you have to get up in the morning, to what extent are you dependent on being woken up by an alarm clock? <small>* must provide value</small>	<p><input type="radio"/> Not at all dependent <input type="radio"/> Slightly dependent <input type="radio"/> Fairly dependent <input type="radio"/> Very dependent</p> <p>reset</p>
4. Assuming adequate environmental conditions, how easy do you find getting up in the mornings? <small>* must provide value</small>	<p><input type="radio"/> Not at all easy <input type="radio"/> Not very easy <input type="radio"/> Fairly easy <input type="radio"/> Very easy</p> <p>reset</p>
5. How alert do you feel during the first half hour after having woken in the mornings? <small>* must provide value</small>	<p><input type="radio"/> Not at all alert <input type="radio"/> Slightly alert <input type="radio"/> Fairly alert <input type="radio"/> Very alert</p> <p>reset</p>

6.	How is your appetite during the first half-hour after having woken in the mornings?	<input type="radio"/> Very poor <input type="radio"/> Fairly poor <input type="radio"/> Fairly good <input type="radio"/> Very good	reset
* must provide value			
7.	During the first half-hour after having woken in the morning how tired do you feel?	<input type="radio"/> Very tired <input type="radio"/> Fairly tired <input type="radio"/> Fairly refreshed <input type="radio"/> Very refreshed	reset
* must provide value			
8.	When you have no commitments the next day, at what time do you go to bed compared to your usual bedtime?	<input type="radio"/> Seldom or never later <input type="radio"/> Less than one hour later <input type="radio"/> 1-2 hours later <input type="radio"/> More than two hours later	reset
* must provide value			
9.	You have decided to engage in some physical exercise. A friend suggests that you do this one hour twice a week and the best time for him is between 7:00-8:00 AM. Bearing in mind nothing else but your own "feeling best" rhythm, how do you think you would perform?	<input type="radio"/> Would be on good form <input type="radio"/> Would be on reasonable form <input type="radio"/> Would find it difficult <input type="radio"/> Would find it very difficult	reset
* must provide value			
10.	At what time in the evening do you feel tired and as a result in need of sleep?	<input type="radio"/> 8:00-9:00 PM <input type="radio"/> 9:00-10:15 PM <input type="radio"/> 10:15 PM-12:45 AM <input type="radio"/> 12:45-2:00 AM <input type="radio"/> 2:00-3:00 AM	reset
* must provide value			

<p>11.</p>	<p>You wish to be at your peak performance for a test which you know is going to be mentally exhausting and lasting for two hours. You are entirely free to plan your day and considering only your own "feeling best" rhythm which ONE of the four testing times would you choose?</p> <p>* must provide value</p>	<p> <input type="radio"/> 8:00-10:00 AM <input type="radio"/> 11:00 AM-1:00 PM <input type="radio"/> 3:00-5:00 PM <input type="radio"/> 7:00-9:00 PM </p> <p style="text-align: right;">reset</p>
<p>12.</p>	<p>If you went to bed at 11:00 PM at what level of tiredness would you be?</p> <p>* must provide value</p>	<p> <input type="radio"/> Not at all tired <input type="radio"/> A little tired <input type="radio"/> Fairly tired <input type="radio"/> Very tired </p> <p style="text-align: right;">reset</p>
<p>13.</p>	<p>For some reason you have gone to bed several hours later than usual, but there is no need to get up at any particular time the next morning. Which ONE of the following events are you most likely to experience?</p> <p>* must provide value</p>	<p> <input type="radio"/> Will wake up at usual time and will NOT fall asleep <input type="radio"/> Will wake up at usual time and will doze thereafter <input type="radio"/> Will wake up at usual time but will fall asleep again <input type="radio"/> Will NOT wake up until later than usual </p> <p style="text-align: right;">reset</p>
<p>14.</p>	<p>One night you have to remain awake between 4:00-6:00 AM in order to carry out a night watch. You have no commitments the next day. Which ONE of the following alternatives will suit you best?</p> <p>* must provide value</p>	<p> <input type="radio"/> Would NOT go to bed until watch was over <input type="radio"/> Would take a nap before and sleep after <input type="radio"/> Would take a good sleep before and nap after <input type="radio"/> Would take ALL sleep before watch </p> <p style="text-align: right;">reset</p>
<p>15.</p>	<p>You have to do two hours of hard physical work. You are entirely free to plan your day and considering only your own "feeling best" rhythm which ONE of the following times would you choose?</p> <p>* must provide value</p>	<p> <input type="radio"/> 8:00-10:00 AM <input type="radio"/> 11:00-1:00 AM <input type="radio"/> 3:00-5:00 PM <input type="radio"/> 7:00-9:00 PM </p> <p style="text-align: right;">reset</p>

16. You have decided to engage in hard physical exercise. A friend suggests that you do this for one hour twice a week and the best time for him is between 10:00-11:00 PM. Bearing in mind nothing else but your own "feeling best" rhythm how well do you think you would perform?

* must provide value

Would be on good form
 Would be on reasonable form
 Would find it difficult
 Would find it very difficult

reset

17. Suppose that you can choose your own work hours. Assume that you worked a FIVE hour day (including breaks) and that your job was interesting and paid by results. Which FIVE CONSECUTIVE HOURS would you select?

* must provide value

12 AM 1 2 3 4 5 6 7 8 9 10 11 AM
 12 PM 1 2 3 4 5 6 7 8 9 10 11 PM

18. At what time of the day do you think that you reach your "feeling best" peak (select one)?

* must provide value

12 AM 1 2 3 4 5 6 7 8 9 10 11 AM
 12 PM 1 2 3 4 5 6 7 8 9 10 11 PM

reset

19. One hears about "morning" and "evening" types of people. Which ONE, of these types do you consider yourself to be?


* must provide value

Definitely a "morning" type
 Rather more a "morning" than an "evening" type
 Rather more an "evening" than a "morning" type
 Definitely an "evening" type

reset

15.6 Demographic Survey

Demographic Survey

Resize font: 

Page 2 of 10

Section 1: Demographic

1.1 Are you Hispanic or Latino?
* must provide value

Yes
 No

reset

1.2 What race do you consider yourself to be? (check all that apply)
* must provide value

American Indian or Alaska Native
 Asian
 Black or African American
 Native Hawaiian or other Pacific Islander
 White
 Other

1.3 What was the last grade you finished in school?
* must provide value

Less than High School Graduate (0-11 years)
 High School Graduate (12 years)
 Some College (13-15 years)
 College Graduate (16 years)
 Post-College (More than 16 years)

reset

1.4 What is your current employment status?
* must provide value

Working full time
 Working part time
 Self-Employed
 Looking for work/unemployed
 Disabled
 Temporarily laid off
 Retired
 Homemaker
 Full-time student
 Part-time student
 Other

reset

1.5 What kind of work do you normally do?
* must provide value

Expand

1.6	What was your family's income this past year (before tax)?	<input type="radio"/> less than \$10,000 <input type="radio"/> \$10,000-\$25,000 <input type="radio"/> \$25,000-\$50,000 <input type="radio"/> \$50,000-\$100,000 <input type="radio"/> \$100,000+	reset
1.7	What is your marital status?	<input type="radio"/> Single <input type="radio"/> Married <input type="radio"/> Widowed <input type="radio"/> Divorced <input type="radio"/> Separated	reset
1.8	How many adults live with you right now?	<input type="text"/>	
1.9	How many children live with you right now?	<input type="text"/>	
1.10	How long have you lived at your current residence?	<input type="text"/>	Years
		<input type="text"/>	Months
1.11	Has your residence been sound-proofed to reduce noise?	<input type="radio"/> Yes <input type="radio"/> No	reset
	What type of home do you live in?	<input type="radio"/> Row home <input type="radio"/> Twin <input type="radio"/> Detached house <input type="radio"/> Apartment/ Room <input type="radio"/> Other	reset

Section 2: Sleep and Health

2.1 Do you use any of the listed noise producing items to help you sleep at night? (Check all that apply)
* must provide value

Fan
 TV
 Music
 Other item that creates noise and helps you sleep
 None

2.2 During the past month how many hours of sleep did you usually get each week night?
* must provide value

2.3 During the past month how many times did you usually wake up and get out of bed each night?
* must provide value

2.4 Do you take naps during the day?
* must provide value

Yes
 No

reset

2.5 On a scale from 1 to 10, how well did you sleep this past month?
* must provide value

1: Very Poorly 2 3 4 5 6 7 8 9 10: Excellent

reset

2.6 Please tell me if the following statements applied always, often, sometimes, rarely, or never this past month:

	Always	Often	Sometimes	Rarely	Never	
a.) My sleep was restless <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset
b.) I was satisfied with my sleep <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset
c.) My sleep was refreshing <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset
d.) I had difficulty falling asleep <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset
e.) I had trouble staying asleep <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset
f.) I had trouble sleeping <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset
g.) I got enough sleep <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset
h.) I have had trouble breathing <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset
i.) I have had headaches <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset
j.) I have had chest pains <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	reset

2.7 Have you ever been diagnosed by a doctor or other health professional with..

	Yes	No
a.) Asthma, Emphysema, COPD or any other condition that affects your ability to breathe normally? <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>
b.) Any heart conditions? <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>
c.) High blood pressure or hypertension? <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>

2.8 In the past month, how many caffeine-containing drinks including coffee, tea, energy drinks, and soft drinks, did you usually have per day?

* must provide value

2.9 In the past month, how often did you drink alcohol?

* must provide value

Every day
 A few days a week
 Once a week
 Once this past month
 Never

2.10 Do you smoke cigarettes, cigars, or pipes?

* must provide value

Yes
 No

2.11 Please tell me if the following statements applied all of the time, most of the time, more than half of the time, less than half of the time, some of the time, or at no time this past month.


	All of the time	Most of the time	More than half of the time	Less than half of the time	Some of the time	At no time
a.) I have felt cheerful and in good spirits <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
b.) I have felt calm and relaxed <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
c.) I have felt active and vigorous <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
d.) I woke up feeling fresh and rested <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
e.) My daily life has been filled with things that interest me <small>* must provide value</small>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Section 3: Noise

3.1	<p>Thinking about the last 12 months or so, when you are here at home, how much does noise from Aircraft bother, disturb, or annoy you?</p> <p>* must provide value</p>	<p><input type="radio"/> Not at all</p> <p><input type="radio"/> Slightly</p> <p><input type="radio"/> Moderately</p> <p><input type="radio"/> Very</p> <p><input type="radio"/> Extremely</p>	reset
3.2	<p>Thinking about the past 12 months or so, when you are here at home, how much does noise from Road Traffic bother, disturb or annoy you?</p> <p>* must provide value</p>	<p><input type="radio"/> Not at all</p> <p><input type="radio"/> Slightly</p> <p><input type="radio"/> Moderately</p> <p><input type="radio"/> Very</p> <p><input type="radio"/> Extremely</p>	reset
3.3	<p>Thinking about the last 12 months or so, when you are here at home, how much does noise from Trains bother, disturb or annoy you?</p> <p>* must provide value</p>	<p><input type="radio"/> Not at all</p> <p><input type="radio"/> Slightly</p> <p><input type="radio"/> Moderately</p> <p><input type="radio"/> Very</p> <p><input type="radio"/> Extremely</p>	reset
3.4	<p>Thinking about the past 12 months or so, when you are here at home, how much does noise in general bother, disturb, or annoy you?</p> <p>* must provide value</p>	<p><input type="radio"/> Not at all</p> <p><input type="radio"/> Slightly</p> <p><input type="radio"/> Moderately</p> <p><input type="radio"/> Very</p> <p><input type="radio"/> Extremely</p>	reset
3.5	<p>How sensitive to any kind of noise do you consider yourself?</p> <p>* must provide value</p>	<p><input type="radio"/> Not at all Sensitive</p> <p><input type="radio"/> Slightly</p> <p><input type="radio"/> Moderately</p> <p><input type="radio"/> Very</p> <p><input type="radio"/> Extremely Sensitive</p>	reset

15.7 Morning Survey

Morning Survey

Resize font: 

Please complete all of the questions.

1.	Subject ID: <small>* must provide value</small>	<input type="text"/>
2.	Last night did you sleep with the windows... <small>* must provide value</small>	<input type="radio"/> Closed <input type="radio"/> Partially Open <input type="radio"/> Completely Open <small>reset</small>
3. At what time did you ...		
	go to bed and switch off the light last night? <small>* must provide value</small>	<input type="text"/> <small>HH:MM</small>
	wake up this morning? <small>* must provide value</small>	<input type="text"/> <small>HH:MM</small>
	get out of bed this morning? <small>* must provide value</small>	<input type="text"/> <small>HH:MM</small>
4.	How long did it take you to fall asleep after you turned the lights off? <small>* must provide value</small>	<input type="text"/> <small>(minutes)</small>
5.	Did you wake up during the night? <small>* must provide value</small>	<input type="radio"/> Yes <input type="radio"/> No <small>reset</small>

6. How do you feel right now?
 * must provide value

0:awake,active,refreshed
 1
 2
 3
 4
 5
 6
 7
 8
 9
 10:tired,dull,sleepy

[reset](#)

7. Please select the statement that best describes how sleepy you feel right now...
 * must provide value

Feeling active, vital, alert, or wide awake
 Functioning at high levels, but not at peak; able to concentrate
 Awake, but relaxed; responsive but not fully alert
 Somewhat foggy, let down
 Foggy; losing interest in remaining awake; slowed down
 Sleepy, woozy, fighting sleep; prefer to lie down
 No longer fighting sleep, sleep onset soon; having dream-like thoughts

[reset](#)

8. Please evaluate last night's sleep:

Falling asleep was:
 * must provide value

0: very easy
 1
 2
 3
 4
 5
 6
 7
 8
 9
 10: very difficult

[reset](#)

My sleep was:
 * must provide value

0: very calm
 1
 2
 3
 4
 5
 6
 7
 8
 9
 10: very restless

[reset](#)

Overall Sleep Quality:
 * must provide value

0: low
 1
 2
 3
 4
 5
 6
 7
 8
 9
 10: high

[reset](#)

9. How bothered, disturbed, or annoyed do you feel by last night's ...

	Not at all	Slightly	Moderately	Very	Extremely
Aircraft noise? * must provide value	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Road traffic noise? * must provide value	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Train noise? * must provide value	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Noise in general? * must provide value	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

10. Other comments?

Expand