Project 017 Pilot Study on Aircraft Noise and Sleep Disturbance

University of Pennsylvania

Project Lead Investigator

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University Participants

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- P.I.: Mathias Basner, Associate Professor
- FAA Award Number: COE-2014-17
- Period of Performance: October 1, 2014 to September 30, 2015
- Task: Pilot study to test an ECG and Actigraphy methodology for monitoring sleep which was developed in earlier phases of this project.

Project Funding Level

The funding amount for this period was $154,000. The cost sharing requirement for this project was met by our international collaborators at the German Aerospace Center (DLR).

Investigation Team

- Principal Investigator: Mathias Basner
- Postdoctoral Researcher: Sarah McGuire
- Research Assistant: Maryam Witte

Project Overview

The most recent U.S. field study on the effects of aircraft noise on sleep was conducted in 1996. Since then air traffic has changed significantly, with an increase in traffic volume, on one hand, and significant improvements in noise levels of single aircraft, on the other. While more recent studies have been conducted, primarily in European Countries, it is unknown whether results from studies performed outside the U.S. can be directly transferred to U.S. domestic airports. Therefore, it is important that U.S. field studies be conducted to acquire current data for varying degrees of noise exposure.

The long-term goal of this project is to derive exposure-response relationships for aircraft noise-induced sleep disturbance that are representative of the exposed U.S. population. As studies will have to investigate samples around multiple airports it will not be possible to use polysomnography (i.e., simultaneous recording of the electroencephalogram, electromyogram, and electrooculogram) to monitor sleep, as this method requires trained personnel at the measurement site in the evening and in the morning and is thus too costly. An alternative methodology of using a single channel electrocardiogram (ECG) and actigraphy to monitor sleep has been examined. This methodology allows the investigation of larger subject samples at lower cost as individuals can be taught how to apply the electrodes themselves. Also unlike polysomnography, awakenings can be identified automatically. As part of previous research, an algorithm for identifying EEG arousals (Basner, Griefahn, Müller et al., 2007) based on increases in heart rate was refined in order to only identify those arousals greater than or equal to 15 seconds in duration. Changes made include modifications to the model parameters, the inclusion of actigraphy data,

and an algorithm to identify sleep onset and the final awakening. High agreement between EEG visually scored arousals and arousals identified using the refined algorithm has been obtained.

The methodology of using actigraphy and ECG to monitor sleep was implemented in a pilot field study conducted around Philadelphia International Airport. This airport was chosen for the pilot study as it was in close distance to the study team and had relevant amounts of nighttime traffic. The purpose of the study was to evaluate the feasibility of using the developed methodology in a field setting and to examine at what aircraft noise exposure level sleep quality may start to differ relative to those not exposed to aircraft noise. Field measurements were completed in the summer of 2015. Data analysis for the study is ongoing and will be completed in 2016. Based on lessons learned from conducting the pilot study, during the next year the methodology for conducting field studies will be simplified even further, and a second field study will be conducted in which equipment is mailed to participant's homes therefore eliminating the need for staff in the field.

Objectives

1. Conduct a pilot study around Philadelphia International Airport to evaluate the feasibility of using an ECG and actigraphy methodology for monitoring sleep
2. Monitor sleep and noise levels in the bedroom for 3 consecutive nights for 40 subjects that were exposed to nighttime aircraft noise and 40 subjects that were not exposed to significant levels of aircraft noise
3. Develop models which relate acoustical properties of single aircraft noise events (e.g., SEL, $L_{AS,max}$) and awakenings
4. Compare the degree of sleep fragmentation between those exposed and not exposed to nighttime aircraft noise
5. Compare models derived in this study to those derived in a study conducted around Frankfurt Airport
6. Determine improvements that can be made to the recruitment process, data collection procedure, and data analysis. Provide recommendations on the methodology for a potential larger study examining sleep in a more representative sample.
7. Collaborate with DLR and other researchers to develop a common methodological approach for future sleep studies which will allow comparisons between studies and data pooling

Research Approach

A 3 night in home sleep study was conducted from July 2014 until July 2015. Forty subjects were enrolled who lived near Philadelphia Airport, and 40 subjects were enrolled that were not exposed to significant levels of aircraft noise and who lived in Philadelphia County.

Subject Recruitment

Ten subjects were recruited by going door to door and hanging flyers in Essington, PA near Philadelphia International Airport. The remaining 70 subjects were recruited by mailing letters to households with the highest L_{Night} levels near the airport and to randomly selected households in the control area. Those enrolled in the study had to be 21 years or older, have normal hearing, Body Mass Index ≤ 35, no children under 5 years of age, have not been diagnosed with a sleep disorder, or had a cardiac arrhythmia.

Physiological Measurements

Each night actigraphy (skeletal muscle movement) and heart rate (ECG) was simultaneously measured. Each morning participants measured their blood pressure using a home monitor; three consecutive measurements with 60 seconds between measurements were completed.

Environmental Measurements

Noise levels inside the bedroom were continuously recorded 24 hours a day using a sound level meter. Indoor sound recordings were also made during the nighttime period. The subjects started the indoor sound recorders each night and stopped the recorder each morning. A less expensive sound recording device was used to measure sounds outside the bedroom window continuously 24 hours a day. The outdoor measurements are only being used for aircraft identification. Temperature, humidity, and light intensity in the bedroom were also measured in order to control in the statistical analysis for the effects of these variables on sleep.

Subjective Assessments of Sleep

Subjects completed surveys on their sleep and health on the first day of the study including the Health Survey (SF-36) (Ware and Sherbourne, 1992), the Pittsburgh Sleep Quality Index (PSQI) (Buysse, Reynolds, Monk, et al., 1989), and the Horne-Ostberg Morningness-Eveningness Questionnaire (Horne and Ostberg, 1976). We also wrote a demographic questionnaire in order to collect basic socio-demographic data as well as responses on annoyance to different noise sources. Subjects also

completed a brief survey each morning on their previous night's sleep, their annoyance to the noise, and their level of alertness and fatigue.

Data Analysis
Models will be developed which relate acoustical properties of single aircraft noise events (e.g., SEL, $L_{AS,max}$) and awakenings. Awakenings will be determined using an automatic algorithm that identifies increases in heart rate and body movement associated with a cortical awakening. Aircraft noise events will be identified by human scorers by listening to both indoor and outdoor recordings and will also be verified using flight schedule data.

Milestones

The following are milestones that were achieved during the past 12 months:

(1) 80 participants were enrolled in the study and field measurements were completed July, 2015
(2) Scoring of the indoor sound recordings have been completed for 20% of the subject nights.

Major Accomplishments

Eighty subjects were enrolled in the study; characteristics of which are listed in Table 1. In order to meet the target of enrolling 40 subjects near the airport, 17 were enrolled from Gloucester City, New Jersey which is an area predominately affected by arrival aircraft and 23 were enrolled from Essington, Pennsylvania which is an area predominately affected by departure aircraft. The subjects in all three study areas were of a wide age range.

Table 1: Characteristics of the 80 participants that were enrolled in the pilot sleep study.

Area	Number of Participants	Age Range (mean)	Gender
Control, Philadelphia PA	40	22-68 (32)	52% Female
Airport, Essington PA	23	23-77 (48)	70% Female
Airport, Gloucester City NJ	17	22-62 (42)	41% Female

For analysis, data for 3 subjects will be excluded. For two of the three, the reason for exclusion is potential health reasons identified based on the heart rate and actigraphy data. An overview of the number of completed physiological and noise measurements for the remaining 77 subjects are listed in Table 2. All subjects except for 1 completed all 3 nights of the study. For 93% of the nights, there was not any data loss in the heart rate measurements due to improper use of the device, or cables or electrodes coming off during the night. For all nights, actigraphy measurements were obtained without data loss. For all but 1% of the mornings, a blood pressure measurement was obtained, with three measurements completed for 94% of the mornings. Subjects also turned on the indoor sound recorder for most nights (91%). There were equipment problems and high background noise levels due to television though on a few nights (6%). All subjective assessments of sleep and health were completed. Overall based on the data that was collected, subjects were able to follow the study protocol and complete sleep and noise measurements for multiple nights unassisted by staff members.

Table 2: Overview of physiological and noise measurement data obtained as part of the pilot sleep study.

Nights of Study Completed (Total Subjects: 77)	
99.0% of subjects	Completed 3 nights/mornings
1.0% of subjects	Completed 2 of 3 nights/mornings
Heart Rate Measurements (Total Nights: 230)	
93.0% of nights	No missing recording periods due to improper use of device, electrodes, cables
6.0% of nights	Partial nights of ECG recordings
1.0% of nights	No valid ECG recording
Blood Pressure Measurements (Total Mornings: 230)	
94.0% of mornings	3 of 3 blood pressure measurements completed
3.0% of mornings	2 of 3 blood pressure measurements completed
2.0% of mornings	1 of 3 blood pressure measurements completed

1.0% of mornings	0 of 3 blood pressure measurements completed
Indoor Sound Recordings (.wav files) (Total Nights: 230)	
91.0% of nights	Full recordings
3.0% of nights	Equipment problems
3.0% of nights	High background noise throughout night (e.g. tv)
3.0% of nights	Device not turned on (Valid 1-sec dB(A) time histories obtained)
Outdoor Sound Recordings (.wav files) (Total Nights: 230)	
95.0% of nights	Full recordings
3.0% of nights	No secure location to place device
2.0% of nights	Equipment problems

Publications

- Basner, Mathias (MD, PhD, MSc), McGuire, Sarah (PhD), Witte, Maryam. "Pilot Sleep Study near Philadelphia International AirportPilot Sleep Study near Philadelphia International Airport," Report Date: August 2016. Project Period: September 2013 – August 2016.
- Basner, M., Brink, M.: Sample size estimation for field studies on the effects of aircraft noise on sleep. Applied Acoustics 74(6): 812-817, 2013
- Basner, M., Elmenhorst, E.-M., Brink, M.: Critical appraisal of methods for the assessment of noise effects on sleep. Noise & Health 14(61): 321-329, 2012.

Outreach Efforts

None

Awards

None

Student Involvement

None

Plans for Next Period

Year 1: Pilot Sleep Study to Test ECG and Actigraphy Methodology

The scoring of the indoor recordings will be completed by using flight operations data to verify aircraft events in the recordings and by having individuals listen to the recordings. For the heart rate and actigraphy data collected, artifacts in the signals will be identified and excluded from analysis and awakenings will be detected using the algorithm that has been developed.

Year 2: Sleep Study to Test Methodology of Mailing Equipment (Airport TBD)

Preparations for a second field study will be completed. For this second study we will further simplify the methodology and reduce the methodological expense by eliminating staff in the field. We will mail out surveys to households around one U.S. airport that has relevant amounts of traffic between 10:00 pm and 7:00 am. The survey will include questions on sleep and health. Participants will also be asked on the questionnaire whether they are interested in taking part in a 5-night in home sleep study. The five night study will include indoor sound recordings and actigraphy and heart rate measurements. During the next period the recruitment questionnaire will be finalized, IRB approval will be obtained, and inexpensive sound recording devices will be acquired and tested.

References

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Basner M, Müller U, Elmenhorst EM, Kluge G, Griefahn B. Aircraft noise effects on sleep: a systematic comparison of EEG awakenings and automatically detected cardiac activations. Physiol. Meas. 2008;29(9):1089-1103.

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Ware JE, Sherbourne CD. The MOS 36-item short-form health survey (SF-36). 1. Conceptual framework and item selection. Med. Care 1992;30(6):473-83.