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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- PI(s): Mathias Basner, associate professor
- FAA Award Number: 13-C-AJE-UPENN-011
- Period of Performance: October 01, 2018, to September 30, 2019
- Task(s):
  - Atlanta (ATL) pilot sleep study: Data analysis

Project Funding Level

This period is a no-cost extension. The funding balance at the start of this period (October 1, 2018) was $45,298. The cost-sharing requirement for this project was fully met by our international collaborators at the German Aerospace Center (DLR) during the original project period ending September 30, 2018.

Investigation Team

- PI(s): Mathias Basner (University of Pennsylvania): study design, data acquisition, data analysis
- Postdoctoral researcher: Michael Smith (University of Pennsylvania): data analysis
- Research assistants: Katharine Casario and Sarah Rocha (both University of Pennsylvania): data acquisition (Sarah Rocha), data analysis (both)

Project Overview

The long-term goal of this line of research is to derive exposure–response relationships for aircraft noise-induced sleep disturbance that are representative of the exposed U.S. population. Studies will have to investigate samples around multiple airports; therefore, it will not be possible to use polysomnography [i.e., simultaneous recording of the electroencephalogram (EEG), electromyogram, and electrooculogram] to monitor sleep because this would require trained personnel at the measurement site in the evening and morning, which would be too costly. An alternative method of using a single-channel electrocardiogram (ECG) and actigraphy to monitor sleep has been examined. This would allow investigation of a greater number of subject samples at lower cost because individuals can be taught how to apply the electrodes themselves. Also, in contrast to polysomnography, awakenings can be identified automatically. Awakenings are defined as brain activations (so-called EEG arousals) that last 15 s or longer. As part of previous research, we refined an algorithm for identifying EEG arousals (Basner et al., 2007) based on increases in heart rate to identify only those arousals ≥15 s in duration, which is the most agreed upon indicator of noise-induced sleep disturbance. High agreement was obtained between arousals scored visually from the EEG and those identified using the refined ECG-based algorithm. The method of using ECG and actigraphy to monitor sleep has been implemented in two pilot field studies to evaluate the quality of data that can be obtained for

unattended physiological and noise measurements. Based on lessons learned, the study protocol is being refined to inform the design and cost of a potential multi-airport study on the effects of noise on sleep.

Task 1 - Data Analysis

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Objective(s)

1. Finish analysis of physiological data received during Philadelphia International airport (PHL) study
2. Finish analysis of acoustical, physiological, and self-reported data of the Atlanta airport (ATL) study
3. Refine and, to the extent possible, automatize the methodology to identify aircraft noise events and maximum sound pressure levels in complex acoustical signals
4. Inform the design of a potential large-scale field study on the effects of aircraft noise on sleep around multiple U.S. airports based on lessons learned from the current field studies
5. Continue our collaboration with colleagues at the DLR to compare, combine, and publish findings from U.S. and German field studies

Research Approach

Based on lessons learned in the PHL sleep study, the methodology was refined and a second pilot study was conducted to evaluate its feasibility on a national scale. ATL airport was was selected for this study in consultation with the FAA and had relevant amounts of nighttime air traffic and a sufficient population from which to sample. To determine the sample regions around the airport, night noise level (L_{night}) contours were provided by the FAA. Additionally, we calculated L_{night} contours for 84 weekdays based on flight track data. For the study, we had 10 sampling regions, 5 east and 5 west of the airport, in the following noise categories: <40 dB (control region), 40<45 dB, 45<50 dB, 50<55 dB, and ≥55 dB L_{night}.

To recruit participants for the study, brief surveys were mailed to randomly selected households within each of the 10 sampling regions. The primary purpose of the survey was to determine the eligibility of individuals to take part in an in-home sleep study. The survey contained questions on the individual's health, sleep, and noise sensitivity. To increase the response rate to the recruitment survey, different incentives, such as a promised gift card or a pre-paid $2.00, were examined. Additionally, survey length and the number of follow-up surveys were varied to determine their effect on response rate. The target number of completed surveys was 200 per 5-dB noise category, for a total of 1000 surveys.

In the survey, participants indicated their interest in taking part in the in-home sleep study, which consisted of 5 nights of unattended ECG and actigraphy measurements and indoor sound recordings. The equipment was mailed to participants' homes, and instruction manuals and videos on how to set up and use the equipment were provided. Mailing the equipment eliminated the need for staff in the field, which significantly reduced the study cost. In addition, mailing the equipment may have increased the response rate because staff did not need to enter participants' homes. For enrolling in the in-home sleep study, participants received varying amounts of compensation. For survey mailing rounds 1 to 5, participants received $20 per night for which measurements were completed. Compensation was increased to $30 per night for mailing rounds 6 to 9, and to $40 per night for rounds 10 to 17. The purpose of increasing the compensation was to evaluate how the response rate changed as compensation increased. This helped us determine a cost-effective compensation for a future multiple airport study. The outcomes for this study were to determine the response rates to both the mail survey and in-home study, assess the feasibility of mailing equipment, and evaluate the quality of data that can be obtained.

Milestone(s)

The following milestones were achieved during the past 12 months:

1. Analysis of the postal survey data in the ATL study was refined and published.
2. Analysis of physiologic and morning questionnaire data in the ATL field study was refined and completed.
3. The physiologic measurement and analysis methodology was refined.
4. The final report for the ATL study was completed and sent to the FAA for review.

Major Accomplishments

Statistical analysis of postal questionnaire data for the pilot study around ATL was refined and finalized (effective sample size $n = 268$). Calculated L_{night} was significantly associated with lower sleep quality [poor or fair; odds ratio (OR) = 1.04 per decibel (dB); $p < .05$], trouble falling asleep within 30 min ≥1/week (OR = 1.06 per dB; $p < .01$), and trouble sleeping due to

awakenings ≥1/week (OR = 1.04 per dB; $p < .05$). L_{night} was also associated with increased prevalence of being highly sleep disturbed (OR = 1.15 per dB; $p < .0001$) and highly annoyed (OR = 1.17 per dB; $p < .0001$) by aircraft noise. Furthermore, L_{night} was associated with several coping behaviors. Residents were more likely to report often or always closing their windows (OR = 1.05 per dB; $p < .01$), consuming alcohol (OR = 1.10 per dB; $p < .05$), using television (OR = 1.05 per dB; $p < .05$), and using music (OR = 1.07 per dB; $p < .05$) as sleep aids. We found no significant relationship between L_{night} and self-reported general health or likelihood of self-reported diagnosis of sleep disorders, heart disease, hypertension, or diabetes.

Analysis of physiologic and morning questionnaire data in the ATL field study was completed. Self-reported awakenings increased as a function of the highest maximum aircraft noise level occurring during the sleep period. Event-related physiologic awakenings increased as a function of the maximum noise level of individual aircraft noise events, although this effect was not significant ($p = .057$), likely because of the low sample size of this pilot study. A larger-scale study among a representative population around multiple airports should be performed, and the approach used in the presented pilot study has been demonstrated to be feasible for this purpose.

We experimentally identified time drift between physiologic and noise measurement equipment and developed synchronization software. We measured the internal device time on the noise recorders and ECG devices relative to actual time determined by Network Time Protocol Internet servers. With our collaborator Uwe Müller at DLR, we developed software to synchronize the timelines of the acoustic and physiologic data. In this time adaptation software, body movements manually identified by auditory examination of the acoustic data were paired against movements detected in the physiologic actigraphy data. Based on the observations of linear drift during recording, we fitted a linear regression to the acoustically and actigraphically scored movements to determine the time drift between data streams within each study night.

The methodology for analyzing event-related awakenings was finalized. A 50-s analysis period will be used, from 5 s before the scored start of an aircraft noise event to 45 s after the start of that same aircraft noise event. This screening window was derived empirically from data collected at four airports—PHL, ATL, Frankfurt (FRA), and Cologne Bonn (CGN)— which maximized slope estimates for the maximum sound pressure level.

A final report on the ATL study was completed. After review by the FAA, changes were implemented and this report was resubmitted in July 2019.

Publications

Peer Reviewed Journal Publications

Basner, M., Witte, M., & McGuire, S. (2019). Aircraft noise effects on sleep – Results of a pilot study near Philadelphia International Airport. International Journal of Environmental Research and Public Health, 16(17): 3178.

Rocha, S., Smith, M., Witte, M., & Basner, M. (2019). Survey results of a pilot sleep study near Atlanta International Airport. International Journal of Environmental Research and Public Health, 16(22): 432.

Smith, M., Rocha, S., Witte, M., & Basner, M. (2020). On the feasibility of measuring physiologic and self-reported sleep disturbance by aircraft noise on a national scale: A pilot study around Atlanta airport. Science of the Total Environment, 718: 137368

Smith, M., Witte, M., Rocha, S., & Basner, M. (2019). Effectiveness of incentives and follow-up on increasing survey response rates and participation in field studies. BMC Medical Research Methodology, 19: 230.

Published Conference Proceedings

Basner, M., Smith, M., Rocha, S., & Witte, M. (2019). Pilot field study on the effects of aircraft noise on sleep around Atlanta International Airport. Presentation and conference paper 23rd International Congress on Acoustics, Aachen, Germany.

Outreach Efforts

Basner, M., Smith, M., Rocha, S., & Witte, M. (2019). Pilot field study on the effects of aircraft noise on sleep around Atlanta International Airport. Oral presentation at 23rd International Congress on Acoustics, Aachen, Germany.

Smith, M., Rocha, S., Witte, M., & Basner, M. (2019) Self-reported sleep disturbance by aircraft noise around Atlanta airport. Poster presentation at SLEEP 2019, San Antonio, TX.

Awards

None.

Student Involvement

None.

Plans for Next Period

We will finalize and publish the final project report. We will continue to disseminate the findings in peer-reviewed journals. We will continue our collaboration with colleagues at DLR to compare findings from U.S. and German field studies and to prepare joint publications.

References

Basner, M., Griefahn, B., Müller, U., Plath, G., & Samel, A. (2007). An ECG-based algorithm for the automatic identification of autonomic activations associated with cortical arousal. Sleep, 30(10):1349-61.