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**NOISE CONTROL FOR QUALITY OF LIFE**

## **Sleep effects of aircraft noise near Paris-Charles de Gaulle airport: results from the pilot study of the DEBATS research program**

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### **ABSTRACT**

DEBATS is an on-going research program aiming to characterize the relations between the aircraft noise exposure and the health status of French residents around three airports. In particular, this program includes a sleep study whose goal is to characterize specifically acute effects of aircraft noise on sleep quality using accurate noise exposure measurements. A pilot study was performed in 2011 in order to test and validate the protocol. Twelve individuals wore a wrist actiwatch for seven nights and completed a sleep diary in order to evaluate their sleep quality. An actiwatch allows detection of wrist movements and is useful for discriminating sleep from wake activity. It has been validated in the assessment of sleep indicators. Simultaneously, a sonometer located in the participants' bedroom recorded their noise exposure during these nights. A second sonometer set up outside (at the bedroom façade) allowed us to identify the aircraft noise and to evaluate the impact of this noise in the participants' bedroom. Thus, energetic as well as noise event indicators have been estimated and a link between these indicators and sleep quality has been investigated. The results of this pilot study are presented and discussed.

Keywords: Noise, Aircraft, Sleep, Residents

### **1. INTRODUCTION**

A national survey carried out in 2005 by the French National Institute for Transport and Safety Research (Inrets<sup>b</sup>) shows that 6.6% of the French population is annoyed by aircraft noise [1]. Many

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surveys carried out both in France and abroad address aircraft noise annoyance [2,3,4] or report adverse effects on sleep quality [5,6,7,8,9,10,11].

Health issues related to airport noise pollutions became over the last years one of the key-questions which public policies want more to take into account. In 2004, the French “Conseil Supérieur d’Hygiène Publique” (CSHPF) delivered its recommendation related to the health protection of people exposed to airport noise: noise around airports is considered as a public health problem not only because of annoyance but also because of sleep disturbances. CSHPF recommended that the knowledge of the French health situation resulting from aircraft noise exposure is improved by performing epidemiological studies. Further to this recommendation, the French Ministry of Health (DGS), in co-operation with the Airport Pollution Control Authority (Acnusa) asked the French Institute of Science and Technology for Transport, Development and Networks (Ifsttar) to implement an epidemiological research program named “Discussion sur les Effets du Bruit des Aéronefs Touchant la Santé” (DEBATS).

## **2. OBJECTIVES AND METHODS**

### **2.1 Objectives**

DEBATS aims to characterize the relations between the aircraft noise exposure and the health status of the French population living in the vicinity of airports, both physically and mentally but also in terms of annoyance.

Some investigations have already been done or are ongoing near a lot of European airports but none has been carried out in France.

This project will support the development of public prevention policies of health risks. DEBATS will contribute to a wider and deeper knowledge of the French sanitary situation resulting from aircraft noise exposure, in particular in terms of sleep disturbances. It will also grant to the request of people living near airports in France. Moreover, DEBATS will make it possible to assess the expected health benefits of the implementation of aircraft noise abatement policies around airports, especially at night.

### **2.2 Methods**

DEBATS is an on-going research program (2011-2018) involving adult residents around French airports [12,13,14]. It includes a sleep study involving 100 individuals living in the vicinity of Paris-Charles de Gaulle airport. Its objective is to characterize specifically and in detail the acute effects of aircraft noise on sleep quality using accurate noise exposure measurements.

The study area was defined on the basis of noise maps produced by Aéroports de Paris with the ‘Integrated Noise Model’ (INM). These maps are based on the actual air traffic during the previous year, applicable air traffic control procedures and infrastructures that will be in use in the year following the date of publication of the order approving the map. They consist of three areas (Cf. Figure 1). The first area indicates a very high level of noise pollution limited by the Lden 70 index curve; the second one indicates a high level of noise pollution between the Lden 70 and Lden 65 index curves; and the last one indicates a moderate level of noise pollution between the Lden 65 and Lden 55 index curves. Within the frame of DEBATS, the French Civil Aviation Authority has assessed a fourth area which indicates a low level of noise pollution between the Lden 55 and Lden 50 index curves. The study area is divided into four zones in terms of Lden: <50 dB, 50-55 dB, 55-59 dB, and ≥60 dB. It is planned to select twenty-five participants in each of these four zones for the sleep study.

The protocol was validated by a scientific committee. A pilot study was performed in 2011 around Paris-Charles de Gaulle airport. Initially, it was planned to select ten participants for this pilot study: two individuals in the <50 dB area, three in the 50-54 dB area, three in the 55-59 dB area and two in the ≥60 dB area. The objective did not consist in evidencing any scientific relationships, but in testing and validating the protocol of the study especially in terms of technical feasibility and subjects’ acceptability. In addition, this pilot study aimed at determining which energetic indicators and noise events indicators are more correlated with sleep quality. The results of this pilot study are presented and discussed.

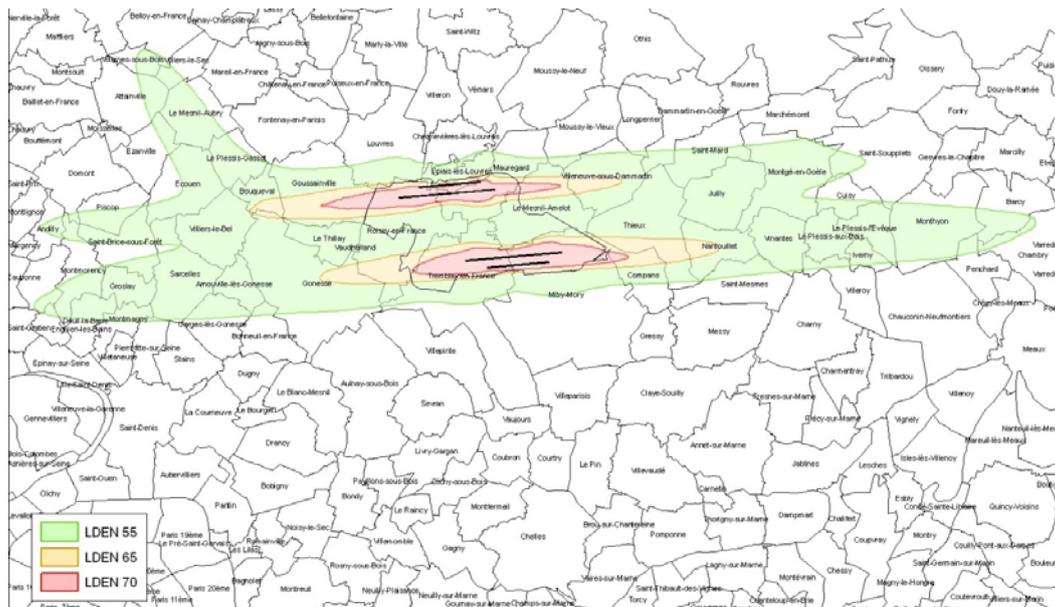


Figure 1 – Paris-Charles de Gaulle airport noise exposure map

In order to answer the questions raised by the sleep study, different types of measurements have been carried at the participants' homes during the pilot study. A first sonometer located in the participants' bedroom recorded their noise exposure at night during a whole week. A second sonometer set up outside (at the bedroom façade) allowed us to identify the aircraft noise and to evaluate the impact of this noise in the participants' bedroom. Based on these measurements, different noise indicators were set up regarding inside and outside of the dwelling: energetic indicators and noise events indicators. Energetic indicators that have been calculated are: LAeq (all sources together), LAeq due to aircraft noise only, LA90, and the contribution of aircraft noise to the global noise level. Noise events indicators that have been produced are: the number of noise events (NNE) due to aircraft, the number of noise events due to aircraft above 62 dB (NA62), 65 dB (NA65) and 70 dB (NA70) outside or above 37 dB (NA37), 40 dB (NA40) and 45 dB (NA45) inside, SEL, and the cumulated amount of time of noise events due to aircraft.

Moreover, the subjects were equipped with a dosimeter during one day in order to estimate their noise exposure outside their home.

Sleep quality was assessed. The participants have worn an actigraph (Actiwatch 4, Philips) on the non-dominant hand for seven nights, when the above-mentioned acoustic measurements were carried out. Simultaneously, they had to fulfill a sleep diary. An actiwatch detected wrist movement and was useful for discriminating sleep from wake activity. Data from the actiwatch have been manually scored using the sleep-wake algorithm, and then, together with the sleep diary made it possible to compute standard sleep variables per night and per subject:

- Sleep onset latency: the amount of time in minutes that it takes for the subject to fall asleep after getting in bed,
- Time in bed: time period measured from "lights out" to the getting up in the morning (TPAL),
- Assumed sleep: the length of time between sleep onset and final wake-up (TPER),
- Actual sleep time: the actual time spent sleeping that is equal to the amount of time between sleep onset and final wake-up minus the actual wake time ( $TTS = TPER - TEIS$ ),
- Actual sleep =  $TTS/TPER$ ,
- Actual wake time: the length of time of awakenings occurring throughout the night (TEIS),
- Actual wake =  $TEIS/TPER$ ,
- Fragmentation index: the ratio of the number of phases of 1-minute immobility to the total number of immobility phases of all duration multiplied by 100,
- Sleep Efficiency: the percentage of time spent in bed in which the subject is actually sleeping (Actual sleep time/Time in bed).

A principal component analysis (PCA) was then conducted assuming that the sleep variables for one subject were independent. The objective was to determine which energetic indicators and noise events indicators are more correlated with sleep quality.

### 3. RESULTS

Twelve individuals agreed to participate to the pilot study. Their distribution according to the four study areas was not homogeneous: one participant was living in the <50 dB area, four participants in the 50-55 dB area, five in the 55-60 dB area and two in the 60 dB + area.

The participants were slightly different from the population of the study area. 75% of participants were females (Cf. Table 1). They were younger: mean age was 42 years old (standard deviation 10.8). 42% of the participants were between 35 and 44 years of age (20% of the population of the study area). 67% of the participants were married (48% of the population of the study area). The education level of the study participants was higher: 58% had a certificate higher than the French high-school certificate (22% of the population of the study area). In terms of employment, 92% had an occupational activity. 83% owned their housing (41% of the population of the study area).

Table 1 – Sociodemographic characteristics of participants

	Pilot study		Population of
	n	%	the study area
			%
<b>Gender</b>			
Female	9	75%	52%
Male	3	25%	48%
<b>Age</b>			
18-25 years	1	8%	15%
26-34 years	2	17%	17%
35-44 years	5	42%	20%
44-54 years	3	25%	18%
55-64 years	1	8%	14%
65-74 years			8%
≥ 75 years			8%
<b>Marital status</b>			
Single	3	25%	40%
Divorced	1	8%	7%
Married	8	67%	48%
Widowed			6%
<b>Educational level</b>			
< French high-school certificate	2	17%	61%
French high-school certificate	3	25%	17%
> French high-school certificate	7	58%	22%
<b>Housing tenure</b>			
Owner occupancy	10	83%	41%
Tenancy	2	17%	59%

The participants followed the protocol very well. Acoustic measurements were available for 10 of the 12 participants due to technical problems of the sonometers and actimetric measurements were available for all the 12 participants. Finally, the database includes 62 nights for which noise indicators and sleep variables were simultaneously available. The PCA was conducted on these 62 nights. The

strongest associations were evidenced between sleep quality and noise events indicators that were estimated inside, in the participants' bedroom (NA37, NA40 and NA45). The detailed results of the PCA will be presented and discussed in details.

#### **4. DISCUSSION**

The participants to the pilot study were slightly different from the population of the study area: there were more females among the participants, they were younger and more educated. This selection bias is very similar to those observed in other epidemiological studies carried out in France. Therefore, if it is possible, participants' selection in the full sleep study will be stratified on gender, age and educational level.

Actigraphy constitutes a reasonably reliable tool in sleep research for producing objective measurements of sleep/wake, but it is not accurate enough for identifying arousals. Therefore, in addition, in the full sleep study, the subjects will wear a heart rate monitor during one night, provided these measurements are validated on some subjects because they were not tested before in terms of technical feasibility and subjects' acceptability. The actimetric measurements and heart rate monitoring will make it possible to characterize arousals more precisely and to investigate a link between aircraft noise and sleep quality.

The PCA is a descriptive method whose objective was to describe and graphically represent correlations between the calculated noise indicators and the sleep variables. But it is not an end in itself. It allowed us to formulate hypotheses that will be investigated more precisely with statistical models in the full sleep study.

The originalities of the sleep study of DEBATS are the following:

- The use of noise event indicators to characterize aircraft noise exposure: most of the epidemiological studies on this topic used energetic indicators.
- Acoustic measurements inside the dwellings which will make it possible to take into account the building outdoor insulation and the opening/closing practice of the windows unlike French and European regulations as well as epidemiological studies which are based on noise exposure at the façade of the buildings.
- Actimetric measurements and heart rate monitoring, very seldom used in epidemiological studies, will make it possible to assess the objective sleep quality of the participants.

#### **5. CONCLUSIONS**

The strongest associations were evidenced between sleep quality and noise events indicators that were estimated inside, in the participants' bedroom. The energetic indicators currently used by the European regulations and recommendations do not seem to be sufficient when sleep quality is considered and need to be completed. However, these results are only based on a dozen of participants living in the vicinity of Paris-Charles de Gaulle airport and need to be replicated on more individuals. That is the reason why 100 participants will be included in the full sleep study, twenty-five in each of the four zones of the study area.

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