

Aircraft Noise and Health Effects: A six-month update (April 2019 – September 2019)

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Chapter 1

Introduction

- 1.1 This report is an update on recent work and findings in the field of aircraft noise and health effects. It covers published research from April – September 2019 and includes relevant findings presented at the Internoise Congress, held in Madrid in June.
- 1.2 The aim of the report is to provide a succinct overview of new work relating to aviation noise and health and it is intended that such updates will be published on a six-monthly basis. This report has been published to provide the public and the aviation industry with a concise and accessible update on recent noise and health developments. It should be noted that the CAA has not validated any of the analysis reported at the conferences, nor takes any view on their applicability to UK policy making. The authors would like to thank Bernard Berry (Bel acoustics) for his valued contribution to the source material.

Chapter 2

Internoise findings

- 2.1 The Internoise Congress was held in June 2019 in Madrid. This year, there was a paucity of presentations concerning aircraft noise and health effects, possibly due to authors choosing to attend the International Congress on Acoustics being held later in the year. The findings from the Internoise meeting relating to aircraft noise and health are summarised in this chapter.
- 2.2 The first study is by Saucy et al who investigated the acute triggering effects of aircraft noise at night on cardiovascular mortality in Switzerland. The paper presents the methodological approach used by the researchers to obtain noise exposure assessment and average noise levels in the specific time intervals prior to death.
- 2.3 The aim of this study TraNQuIL (Transportation Noise: Quantitative Methods for Investigating Acute and Long-Term Health Effects) was to investigate acute effects of aircraft noise on myocardial infarction, stroke and other ischemic cardiovascular causes of mortality by means of a case-crossover study. In addition to assessment of the exposure-response relationships for different time-windows of exposure during the night preceding death, the cumulative effects of several nights preceding the event were looked at.
- 2.4 The case-crossover design allows the investigation of acute health effects for time-varying exposures such as air pollution or noise. The exposure levels at a given time when an event occurs (case events) are compared to the exposure when no event occurs (control events). Due to the daily variation of aircraft movements at Zurich airport, noise exposure varied between study days (case days) and control days. There has been a night flight ban between 23:30 and 06:00 in place since 2010, and before that was from 00:30 to 05:00 or 06:00 for approaches and departures, respectively.
- 2.5 The authors identified all deaths from the Swiss National Cohort occurring near Zurich airport between 2000 and 2014. These included 22,000 cases of cardiovascular disease, and 3000 Myocardial Infarctions. Outdoor noise exposure at participants' home addresses was calculated for the night preceding death as well as 3 to 4 control nights selected within the same month, using calculated aircraft noise impact for each registered flight. Only those individuals who had potentially been exposed to increased aircraft noise exposure were included in the study. This was determined by the criteria used in the Zurich Aircraft Noise Index, which is an index for the number of highly annoyed and highly sleep disturbed (minimum LAeq of 37 dB during the day and/or 47 dB during the night). Noise exposures for each individual at their home address was

obtained for the night prior to death and for the control nights, by using the list of aircraft movements which includes detailed information on all flights landing or taking off from Zurich airport.

- 2.6 The authors focussed on assessing only the night time aircraft noise exposure, looking at the effects of noise exposure on mortality during sleeping hours.
- 2.7 The death cases were each matched with 3 or 4 control dates (the same day of the week in the same month), and separate methodology used for deaths occurring at night (23:00 – 07:00) versus the daytime period (07:00 – 23:00). In the death cases occurring at night, noise exposure was calculated for the two hours prior to death. For people who died during the day the exposure windows were:
- 19:00-23:00: Evening
 - 23:00-23:30: Reduced air traffic
 - 23:30-06:00: Flight ban
 - 06:00-07:00: morning
 - 23:00-07:00: overall night
- 2.8 The results indicated that for both metrics Leq and Lmax, noise exposure was highest for the evening exposure window, and lowest during the core night. For deaths occurring during the daytime, the average Leq of the time windows ranges from 20 -45 dB, and the Lmax average values range between 40 to 60 dB, with the highest values of around 100 dB. This is shown in Figure 1:

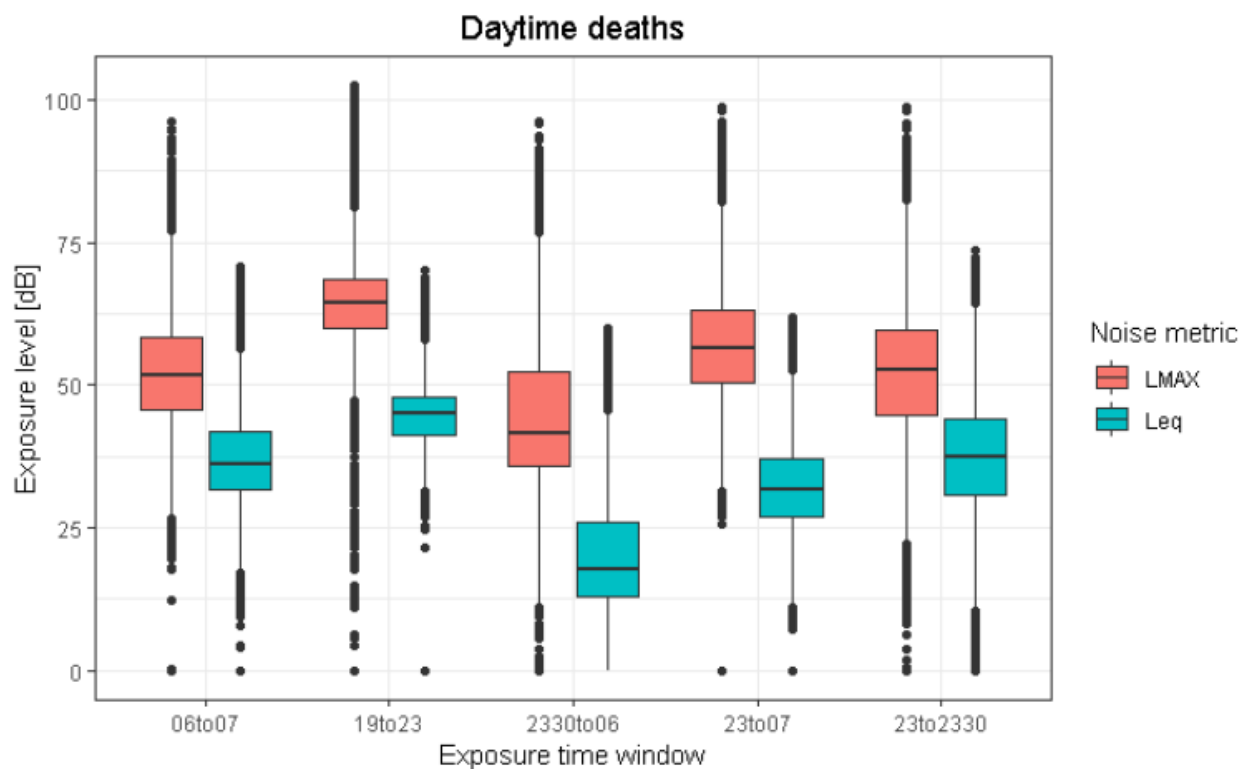


Figure 1: Boxplot of the noise exposure levels Lmax and Leq for the different time windows for all events (case and control) for daytime deaths between 2000-2014. Central line represents the median value, squares the interquartile range (IQR) and the whiskers the lower and upper limits ($-1.5 \times \text{IQR}$ and $1.5 \times \text{IQR}$). Reproduced from Internoise proceedings.

- 2.9 For the deaths occurring at night, average Leq for the preceding two hours was 36 dB with maximum values of around 65 dB, and the average Lmax for this period was 57 dB with maximum values of around 85dB. These are shown in Figure 2.

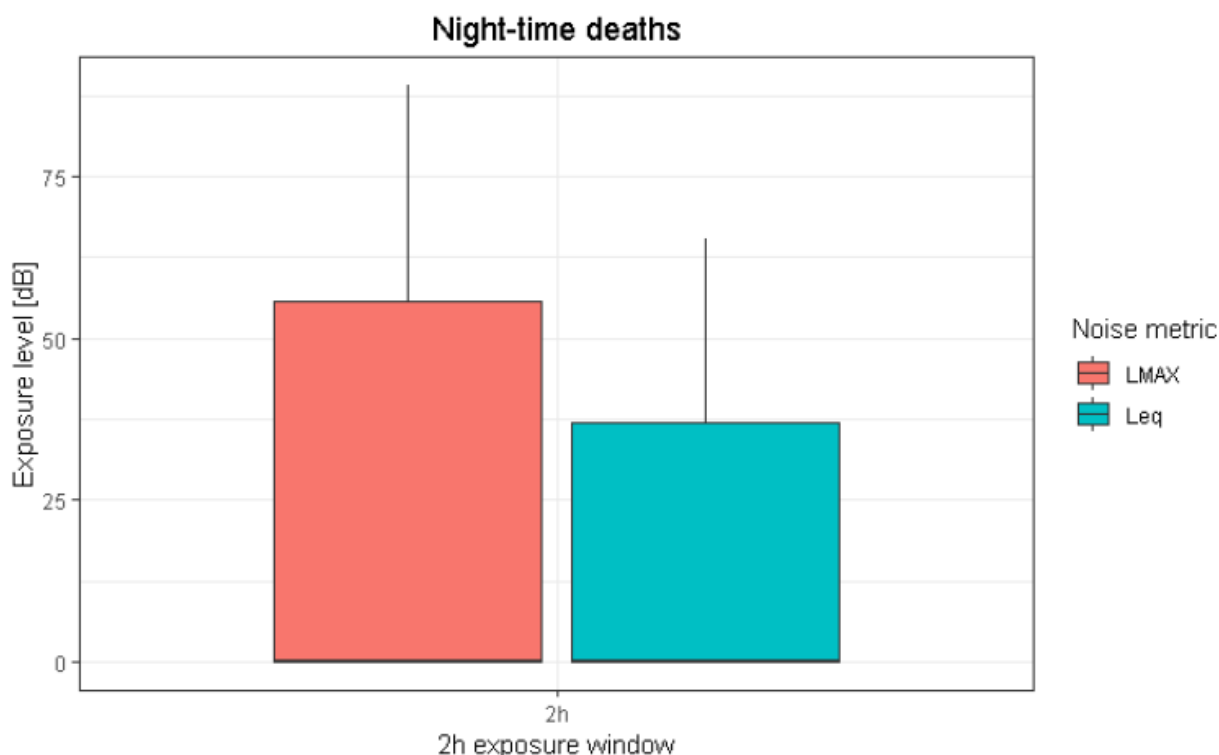


Figure 2: Distribution of the noise exposure levels Lmax and Leq for the 2h window for all events (case and control) for night-time deaths between 2000-2014. Central line represents the median value, squares the interquartile range (IQR) and the whiskers the lower and upper limits ($-1.5 \times \text{IQR}$ and $1.5 \times \text{IQR}$). Reproduced from Internoise proceedings.

- 2.10 The authors explain that the methodology used in this study allows for flexibility with the choice of exposure events, and precision due to the use of the list of movements and previously calculated noise footprints for different aircraft types and air routes. They suggest that this is a suitable method for case-crossover studies looking at short-term or transient effects of noise on health. A follow-up study will extend the analysis to 2016.
- 2.11 Ribeiro et al authored a paper on the health impact of noise in the greater Paris metropolis, focussing on healthy life years lost. Bruitparif (a non-profit environmental organisation responsible for monitoring the environmental noise in the Paris agglomeration) designed a methodology for assessing health impacts per square of territory and per municipality within Paris. Using calculation of Disability Adjusted Life Years (DALYs), the paper describes the impact of transportation noise sources (road, rail and aircraft) on the various regions of Île de France (the area of Northern Central France, surrounding Paris). Within the Île-de-France region, 14 urban agglomerations representing a total of 436 municipalities and 10.1 inhabitants are included: the Greater Paris Metropolis (131 municipalities, nearly 7 million inhabitants) as well as 13 agglomeration communities or urban communities.

- 2.12 Bruitparif used the methodology recommended by the World Health Organisation (WHO) to calculate DALYs, alongside maps with a 250 m² grid and at the level of the municipality to demonstrate the impact of transportation noise on health. Statistical results were provided for the area of study as a whole, as well as for each urban agglomeration, and for each municipality.
- 2.13 The results indicated that transportation noise is responsible for the loss of 107,766 DALYs every year within the region of Île-de-France. The results broken down further into annoyance and sleep disturbance can be seen in Table 1. 43% of total DALYs are lost due to annoyance, and those lost to sleep disturbance account for 57% of the total.

DALY	Road	Rail	Air	Total
Sleep disturbance	33 613	15 088	12 227	60 929 (57%)
Annoyance	31 994	8 352	6 491	46 837 (43%)
Total	65 607 (61%)	23 440 (22%)	18 718 (17%)	107 766

Table 1: DALYs lost to transportation noise in the Paris agglomeration.

- 2.14 Road noise is the largest contributor to DALYs, with 61% of the total being due to road noise, 22% attributed to rail noise and 17% associated with aircraft noise.
- 2.15 The authors state that the DALYs lost every year within the region of Île de France have an economic cost of 5.4 billion Euros per year. Noise pollution is the second-highest cause of death within environmental risk factors in urban environments, with air pollution being the leading cause of death. When compared with previous results for this region between 2011 and 2015, the estimate of the number of DALYs lost to transportation noise has risen 43% (75,000 to 108,000). The figure of aircraft noise-related DALYs has risen by a factor of 3.7, with those related to rail noise increasing by a factor of 3.5. This is due to the incorporation and use of the new exposure-response relationships and limits recommended by the WHO in their update to their Guidelines in October 2018. These guidelines define the recommended values for exposure to transport noise, as well as new exposure-response relationships that make it possible to compare levels of exposure to noise, as estimated by strategic noise maps, and the main health effects of noise.
- 2.16 The average citizen within this region now loses 10.7 months per lifetime, compared to 7.3 in 2015. The study has revealed that in certain sectors exposed to multiple aircraft and land sources, the individual health risk is now greater than 3 healthy life-years lost compared to 18 months in 2015.

- 2.17 The authors explained that this study may be used to highlight where best to focus resources by assisting stakeholders in preparing the various environmental noise action plans in 2019.
- 2.18 A study on the assessment of health effects of aircraft noise on residents living around Noi Bai airport, Vietnam, was authored by Trieu et al. The study design involved two surveys on the health effects of aircraft noise being administered to 13 sites around the airport, during November 2017 and August 2018. The aims of the study were to investigate the relationship between aircraft noise exposure levels and general health, and to provide clarification on whether there is a link between aircraft noise and cardiovascular disease in residents living around the airport.
- 2.19 This study was conducted at 13 survey sites which were selected from the previous surveys in 2014 and 2015. Noise exposure was measured by noise monitors in a resident's house for each of the sites during the first phase of the study. For the second phase, noise exposure was calculated using noise contour maps and operation data. The surveys were conducted face-to-face, with questions on health answered by self-reporting in the first phase, and with measurements taken of blood pressure and heart rate in phase 2. The second phase survey included questions on medication use, and questions relating to sleep quality and insomnia were present in both phases.
- 2.20 A total of 623 and 132 responses were obtained in phase 1 and phase 2, respectively. There was a noticeable change in the number of flights in the evening between the two studies, with a decrease from 82 to 25. The number of flights in the night-time period increased by nearly 2.5 times, from 74 to 171.
- 2.21 The results suggested that although there was a high rate of high blood pressure among the people living around the airport, there was no significant association with noise exposure levels. The two significant factors that were associated with high blood pressure in this population were age and alcohol consumption. A significantly higher rate of insomnia was found at survey phase 2, when the number of night flights had increased. This is perhaps unsurprising given the large increase in night flights. In terms of annoyance, there was no difference found between the two phases of the study. It should be noted that it is not known whether the questions relating to annoyance are the ISO standard scales as specific details of the questions on annoyance, health and sleep disturbance were not included in the paper.
- 2.22 Truls Gjestland presented his paper on the criticisms of the WHO Guidelines, published in October 2018. This systematic review of the basis for WHO's new recommendation for limiting aircraft noise annoyance has been well documented, and a description of this paper – and subsequent response by Guski has been detailed in the previous update CAP report 1713. In order to avoid repetition this paper will not be re-visited in this report.

Chapter 3

Other research

Cardiovascular Disease

- 3.1 Pyko et al published their research on transportation noise and development of ischaemic heart disease (IHD) and stroke. This was a longitudinal study in over 20,000 residents in Stockholm County and examined associations between road, railway and aircraft noise exposure and the incidence of IHD and stroke. Long-term noise exposure from each source was estimated, and questionnaires were administered to obtain information on risk factors and lifestyle.
- 3.2 The results suggested that there were no associations between transportation noise and the incidence of IHD or stroke. Road and aircraft noise was related to IHD in women with Hazard Ratio¹ (HR) of 1.11 (95% CI 1.00 to 1.22) and 1.25 (95% CI 1.09 to 1.44) per 10 dB Lden, respectively. The authors found that when both sexes were analysed together there was a higher risk of IHD in people exposed to all three noise sources at levels ≥ 45 dB Lden, with a HR 1.57 (95% CI 1.06 to 2.32), and a similar result for stroke (HR 1.42; 95% CI 0.87 to 2.32). The authors concluded that although no associations were found between transportation noise exposure and IHD or stroke overall, the results suggest an increased risk of IHD in women exposed to road or aircraft noise, and also those people who are exposed to all three noise sources.
- 3.3 Siedler et al published research findings on combined transportation noise sources and associated health effects. The aim of the study was to better understand how the combined exposures result in an increased risk of health effects such as depression and cardiovascular disease, and which model is the most appropriate to use. The Akaike information criterion (AIC) is used to compare two different models estimating the disease risks of combined traffic noise. The study compared the conventional energetic noise addition model with an epidemiological risk multiplication model, and aimed to determine which model is better at predicting the risks of combined traffic noise. The analyses were based on the NORAH study on disease risks, which used data from people who were insured with three large health insurance companies around the Rhine-Main Airport, resulting in around one million people in total.

¹ Hazard ratio (HR) is a measure of how often a particular event happens in one group compared to how often it happens in another group, over time. The hazard ratio is a relative measure of effect and not absolute risk. The confidence interval (CI) is a range of values, above and below a finding, in which the actual value is likely to fall. The confidence interval represents the accuracy or precision of an estimate.

- 3.4 In the energetic noise addition model, the disease risk is arrived at by summing the combined noise pressure levels. The authors give the example of a combined exposure to 60 dB of railway noise and 60 dB of road traffic noise would lead to a measurable noise pressure level of 63 dB (which is equivalent to a doubling of energy, because decibels are on a logarithmic scale), and this noise pressure level of 63 dB would be used in the noise addition model to predict disease risk. They explain that it is currently unclear if the health effects of this combined exposure can really be equated with the health effects of a 63 dB exposure to one type of traffic noise.
- 3.5 The authors go on to explain the risk multiplication model, which treats different noise sources as separate risk factors and examines their related disease risks, and then, combines these as predictors in a regression model to estimate their combined risk. Thus, it does not simply assess the combination of noise pressure levels, but instead, the combination of multiple disease risk factors (i.e. noise sources). These risks are multiplied since standard epidemiological regression models are based on multiplicative interaction between different risk factors. For instance, assuming the risk increase for traffic noise starts at 40 dB, multiplying the health risks of two different types of traffic noise of 60 dB each would result in a combined risk equivalent to the health risk of one type of traffic noise alone of 80 dB: 40 dB (the baseline risk) plus two times 20 dB (i.e. the excess risk at 60 dB is calculated as the difference 60 dB – 40 dB).
- 3.6 The accuracy of the model used is important as the risk outcomes of the multiplication model are likely to be higher than those predicted by the usual energetic addition model. As a result this could have implications for noise protection measures and planning decisions.
- 3.7 Over 130,000 cases of cardiovascular disease (Myocardial infarction, stroke, heart failure and/or hypertensive heart disease) diagnosed between 2006 and 2010 were included and compared with over 280,000 control subjects who did not have any cardiovascular disease. In addition over 77,000 depression cases were included, as well as over 290,000 control subjects. Address-specific exposure to aircraft, road and railway traffic noise in 2005 was estimated for all cases and control subjects. The exact methodology for each approach is explained in detail in the paper.
- 3.8 The results indicated that for this study the energetic addition model did not accurately reflect the cardiovascular and depression risk from combined traffic noise sources. The risk multiplication model resulted in a better fit for both health outcomes. The authors liken the results to the theory of “the whole being more than the sum of its parts”. In a discussion of the strengths and weaknesses it is explained that a particular strength of the study is that for each source of traffic noise (road, rail and aircraft) continuous noise measures had precisely been assessed for each address in the study area, using most recent international

guidelines and multiple information sources. The weaknesses included a lack of temporal data such as the details of real combined exposure to more than one type of traffic noise at the same daytime or night-time period. It is also noted that the study population was determined by relatively high noise exposure and therefore the results cannot be assumed to be the same for areas with a lower noise exposure.

- 3.9 In practical terms, the authors suggest that this finding of higher disease risks associated with exposure to combined noise sources has implications for residential planning, for example the avoidance of situating roads and railway lines in parallel in the future in densely populated areas. It is stressed that further large-scale studies are required in order to confirm the results from this research, with a particular focus on combined exposures and health outcomes.
- 3.10 However, it is important to point out that in order to provide a sound basis specifically for the derivation of concrete traffic-noise induced disease risks and preventive measures, further large-scale epidemiological studies will be required, specifically focusing on the effects of combined exposure to different types of traffic noise.
- 3.11 Rojek et al investigated the relationship between long-term aircraft noise exposure, blood pressure profile, and arterial stiffness in a study population in suburban Krakow, Poland. The chosen study areas were exposed to high (> 60 dBA Lden) and low (< 55 dBA Lden) aircraft noise levels with low traffic noise exposure of (< 55 dBA Lden). 101 participants were in the high noise exposure group, and 100 were in the non-exposed group. Questionnaires on lifestyle, medical history and annoyance were administered to the participants as well as their physical examination. Study examinations and surveys were performed consecutively on one day in the morning: standardised questionnaire, BP measurements, pulse wave analyses, echocardiographic measurements, and set up of ambulatory BP monitoring (ABPM).
- 3.12 The results indicated that there was no effect of aircraft noise on the incidence of arterial hypertension, but there was an association between aircraft noise exposure and office (i.e. when the measurement was taken in the study setting) and night-time Diastolic Blood Pressure (DBP). In addition, the authors found long term aircraft noise exposure was associated with more advanced arterial stiffness, and unfavourable left ventricle diastolic function changes. Accelerated arterial stiffening was observed in those exposed to aircraft noise, even in those participants who had a normal blood pressure, to a degree depending on noise annoyance. These differences were independent of age, sex, BMI, education, time spent at home, smoking status, alcohol consumption, and antihypertensive treatment.

Sleep Disturbance

- 3.13 Smith et al. published findings of a study into self-reported sleep disturbance from aircraft noise around Atlanta airport. Surveys were sent by post to randomly selected homes around Atlanta airport, which resulted in 290 respondents. Outdoor aircraft noise L_{night} levels between 22:00 – 07:00 were calculated for each household, and logistic regression analysis was applied to each response variable. In addition to questions relating to sleep quality, noise-induced sleep disturbance, coping strategies and health conditions, the questionnaires included questions on age, sex, BMI, education and employment.
- 3.14 The results indicated that L_{night} levels were significantly associated with a decrease in sleep quality, increased frequency of difficulty falling asleep, and increased difficulty in staying away during daytime hours. An increase in L_{night} noise levels were also associated with a significant increase in noise-induced sleep disturbance and annoyance. Outcomes such as diagnosed sleep disorders, hearing impairment, hypertension, arrhythmia, migraine and diabetes were not associated with aircraft noise levels at night.
- 3.15 Elmenhorst et al examined the effects of road, railway and aircraft noise on sleep in three laboratory studies. There are many studies on annoyance that suggest that railway noise is the least annoying, followed by road traffic noise, with aircraft noise causing the highest rate of annoyance. The authors explain that with sleep disturbance, the order is often reversed i.e. aircraft noise is the least likely to cause awakenings, with railway noise producing the highest number of awakenings. This study pooled data from three laboratory studies that were conducted at the German Aerospace Centre, Cologne and Leibniz Research Centre for Working Environment and Human Factors in Dortmund. Nearly 110,000 noise events were produced, and resulting awakenings were assessed by polysomnography in 237 participants. Polysomnography is the continuous recording of specific physiologic variables during sleep. Polysomnography typically records brain wave changes (electroencephalogram), eye movements (electrooculogram), muscle tone (electromyogram), respiration, electrocardiogram (EKG), and leg movements. This technique, whilst being the gold standard for studying sleep disturbance, is time-consuming and expensive, and there is a lack of large-scale studies of this nature, hence the decision to pool the three studies:
1. STRAIN (Study on human specific response to aircraft noise) study at the German Aerospace Center, Cologne: 112 participants (65 female, 47 male) with an average age of 38.1 years.
 2. AIRORA (Effects of air, road and rail traffic noise) study at the German Aerospace Centre, Cologne: 72 participants (40 female, 32 male) enrolled in the study with a mean age of 40.3 years.

3. IfADo study at the Leibniz Research Centre for Working Environment and Human Factors, Dortmund: 53 participants (26 female, 27 male) were examined with a mean age of 23.4 years.

3.16 The exact design and methodology for each study is given in detail in the paper. An overview of the number of events for each noise source, and participants in each study is shown in Table 2.

Category	STRAIN Study	AIRORA Study	IfADo Study	Total Number
Number of participants	112	72	53	237
Number of road noise events	-	9908	25,739	35,647
Number of railway noise events	-	10,014	17,666	27,680
Number of aircraft noise events	25,479	9741	11,289	46,509
Total number of noise events	25,479	29,663	54,694	109,836

Table 2: Number of participants and noise events used for analyses from the three major traffic noise sources that were played back in the three different studies.

3.17 In terms of the regression model, the predictors A-weighted Sound Pressure Level (SPL) and Tr (Tr = steepest slope of the event curve as rise time of the maximum A-weighted SPL of a noise event [dB/s] were both highly significant acoustical predictors for awakenings. There was a significant interaction between maximum a-weighted SPL and aircraft noise, which indicated that the slope of the exposure-response curve was not as steep as those found for road and railway noise. This is shown in Figure 3:

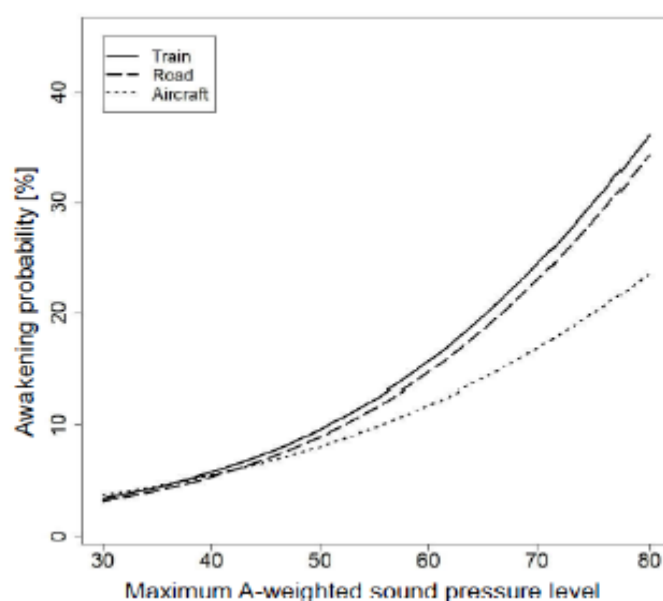


Figure 3: Ranking of the probability for sleep stages changed to awake and Stage 1 due to air, road and railway noise depending on the maximum A-weighted sound pressure level of the noise event.

- 3.18 The results indicate that the probability to wake from equal maximum A-weighted sound pressure levels (SPL) was highest for railway noise, followed by road noise and aircraft noise was the least likely noise source to result in awakenings at the same SPL. There was no significant difference in the awakening probability between road and railway noise ($p = 0.99$). The authors point out that at 70 dB SPL, it was more than 7% less likely to wake up due to aircraft noise compared to railway noise. This is the opposite to the findings for annoyance responses, and the authors stress the importance of including sleep metrics in addition to annoyance levels in noise legislation decision-making.
- 3.19 Nassur et al investigated the effects of aircraft noise exposure on heart rate during sleep in the population living near living near the Paris-Charles de Gaulle and Toulouse-Blagnac airports. This study was an extension of the DEBATS study and included 112 participants.
- 3.20 Exposure to aircraft noise at home was measured continuously during eight days, with two sound meters being positioned at the home; one outside the bedroom façade and one within the bedroom to measure interior SPL. For one of the nights of the eight, the participants wore an Actiheart, a monitor that measures and records heart rate. The Actiheart measurements were used to determine the number of heart beats per minute (HR) of each participant every 15 seconds during their sleep. The two sound level meters and the Actiheart monitor were synchronized at the beginning of the measurements to the nearest second. The recording dates of the SPL and heart rates did not match for 14 subjects who were therefore excluded from analysis, resulting in measurements from 92 of the 112 subjects being used for a total of 92 nights.
- 3.21 The heart rate at 15 seconds prior to an acoustic event was used as a baseline measure, and compared to the mean HR during the event, and again at 15 and 30 seconds afterwards.
- 3.22 Three variables were therefore constructed:
1. HR1 = the difference between the heart rate during the event and the heart rate before the event in beats per minute,
 2. HR2 = the difference between the heart rate 15 s after the event and heart rate before the event in beats per minute,
 3. HR3 = the difference between the heart rate 30 s after the event and the heart rate before the event in beats per minute.
- 3.23 A further variable, HRA-, was also determined: heart rate amplitude during an acoustic event due to aircraft noise. HRA was calculated as the difference between the maximum and minimum heart rate during an acoustic event, in beats per minute.

- 3.24 The results from modelling used to assess the effects of acoustic events linked to aircraft noise on heart rate during sleep is shown in Table 3.

$L_{Amax,1s}$	HR1	HR2	HR3	HRA
	Estimate (95% CI)	Estimate (95% CI)	Estimate (95% CI)	Estimate (95% CI)
Model 1	-0.01 (-0.11;0.09)	0.03 (-0.11;0.17)	0.02 (-0.11;0.16)	0.27 (0.06;0.47)
Model 2	-0.04 (-0.15;0.07)	-0.02 (-0.18;0.14)	-0.04 (-0.19;0.11)	0.34 (0.13;0.55)

Model 1: univariate model including $L_{Amax,1s}$; Model 2: multivariate model including $L_{Amax,1s}$ gender, age, body mass index (BMI), physical activity, tobacco consumption, alcohol consumption, cardiovascular disease, hypertension, elapsed time after sleep onset, and background 10 min before event; Per 10 dBA increase; HR1 = heart rate during event—heart rate before event; HR2 = heart rate 15 s after event—heart rate before event; HR3 = heart rate 30 s after event—heart rate before event HRA = Amplitude during event; Bold values are statistically significant $p < 0.05$.

Table 3: Analysis of event-related heart rate response.

- 3.25 The regression models were applied, taking into account potential confounding factors, to investigate the relationship between energy indicators and heart rate during sleep measured every 15 s. Event-related analyses were also carried out in order to study the effects of an acoustic event associated with aircraft noise on heart rate during sleep. In both models (univariate and multivariate) there was no association found between aircraft noise exposure characterised by $L_{Amax, 1s}$ and the differences between the heart rates at 15 or 30 seconds afterwards and before the event. However, the univariate and multivariate models highlighted a significant positive association between $L_{Amax,1s}$ and the heart rate amplitude during an aircraft noise event (HRA). When the analysis was limited to only those participants who had lived at the same address for at least 5 years, the results remained unchanged, suggesting no evidence of habituation.

Annoyance

- 3.26 Brink et al reported results from a survey on exposure-response relationships for road, rail, and aircraft noise annoyance with respect to differences between continuous and intermittent noise. The aim of the study was to look at exposure-response relationships between percentage highly annoyed (HA) and aircraft, road and railway noise measured in L_{den} . In addition, The authors also wanted to clarify the extent to which the acoustic indicator Intermittency Ratio (IR) predicts noise annoyance.
- 3.27 Intermittency Ratio (IR) reflects the ‘eventfulness’ of a noise exposure situation with the possibility of use alongside the common metrics such as L_{Aeq} . Regarding noise effects on health and wellbeing, average measures often cannot satisfactorily predict annoyance and health effects of noise, particularly sleep disturbances. It has been hypothesised that effects of noise can be better explained when also considering the variation of the level over time and the

frequency distribution of event-related acoustic measures, such as for example, the maximum sound pressure level. IR is defined as the ratio of the event based sound energy to the overall sound energy.

- 3.28 The study used a random sample of over 5500 residents exposed to transportation noise all over Switzerland, with source-specific noise exposure calculated for each person. Annoyance was measured using the ICBEN 11-point scale, and other outcomes such as sleep disturbance, sleep habits, coping style, general health, noise sensitivity and mental health-related were also investigated. The survey was carried out in 4 waves at different times of the year.
- 3.29 The results indicated that for all noise sources there were significant associations between L_{den} and %HA after controlling for confounders and independent predictors such as IR (measured over 24 h), exposure to other transportation noise sources, sex and age, language, home ownership, education level, living duration, temperature, and access to a quiet side of the dwelling. These results are shown in Figure 4.

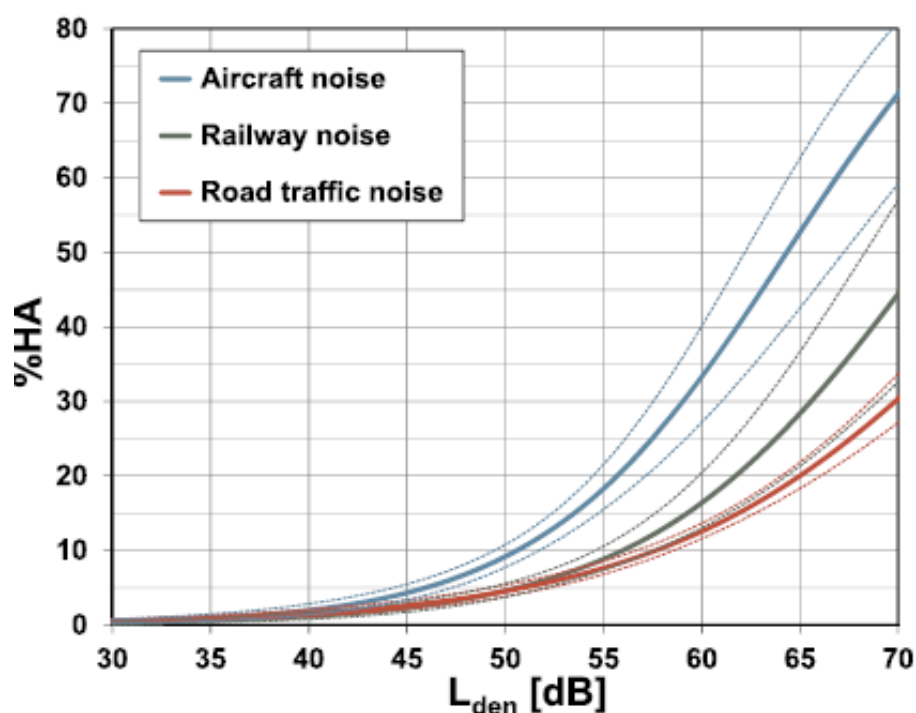


Figure 4: Exposure-response curves for the percentage highly annoyed (%HA) by road, rail, and aircraft noise, including 95% CI.

3.30 Figure 5 illustrates the %HA as a function of IR for each of the noise sources at two chosen Lden levels.

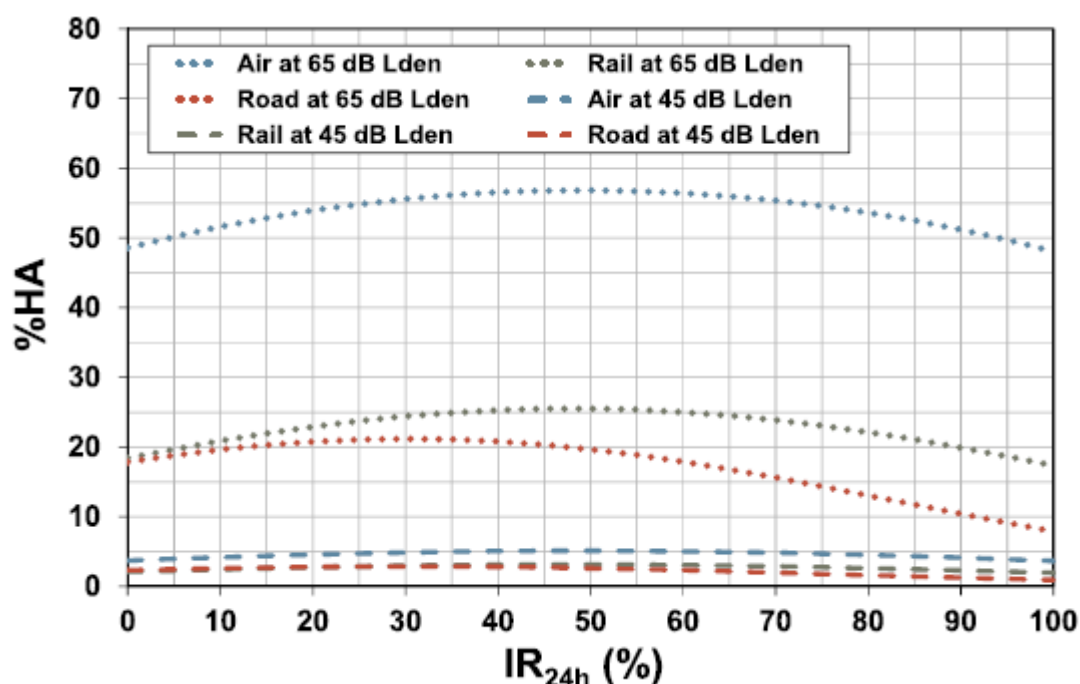


Figure 5: Percentage highly annoyed (%HA) by road, rail, and aircraft noise as function of IR_{24h} for two different Lden values (45 and 65 dBA Lden).

3.31 The results indicate the aircraft noise annoyance scores are higher than those given in response to railway and road traffic noise at the same Lden level, and railway noise was more annoying than road noise. In terms of the inclusion of the IR metric, in this study road traffic noise occurred in very different temporal patterns, from relative continuity to high intermittency. The authors suggest that the inclusion of the IR metric in the exposure-response model for %HA could explain differences of more than 6 dB between road traffic noise exposure situations with low (10%) or high (90%) IR_{24h}, possibly due to the effect of different durations of noise-free intervals between events. It is proposed that this study highlights that the temporal distribution of sound energy from road traffic noise probably has an influence on annoyance reactions and therefore could be considered in the rating of road traffic noise in the future. The predictive value of IR was weaker with railway noise and IR was not linked to aircraft noise annoyance.

Chapter 4

Summary

- 4.1 This report has provided a summary of some of the main findings in the past six months (April -September 2019) with regards to aircraft noise and health effects. It has included the relevant findings from the Internoise Congress held in June, and other significant research into aircraft noise and health outcomes. It is expected that summary reports such as these will be published on a six-monthly basis and continue to include all health outcomes in relation to aircraft noise exposure. The International Congress on Acoustics was held in Germany in September 2019. The next update report will include relevant findings presented at this meeting.

Chapter 5

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