Aircraft Noise and Health Effects: A yearly update

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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 the past year (April 2018 – April 2019) and includes relevant findings presented at the Euronoise and Internoise Congresses, held in May and August, respectively. A discussion on the World Health Organisation's updated Noise Guidelines for Europe, published in autumn 2018, is also included.

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 yearly 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.

1.3 Acknowledgement: The authors are grateful to Bernard Berry (Bel-acoustics.co.uk) for his valued contribution of source material referred to in the report.

Chapter 2
Euronoise findings

2.1 Euronoise 2018 (the 11th European Congress and Exposition on Noise Control Engineering), was held in Crete in May 2018 and various papers on noise and health were included in the proceedings.

2.2 These included a Swedish paper by Pyko et al, which examined transportation noise (road, rail and aircraft) and the incidence of hypertension. The study was a longitudinal design in over 4,800 Stockholm residents who were taking part in a diabetes prevention programme between 1992 and 2006. The time-weighted average noise level at the most exposed façade of the buildings five years preceding the study was used as the indicator of noise exposure. Information regarding hypertension was used from clinical examinations and questionnaires performed approximately nine years apart. Information on potential individual and contextual confounders was also obtained through the questionnaires and registers.

2.3 21% of people studied were exposed to road traffic noise of 45 dBA Lden, 11% were exposed to aircraft noise and 3% to railway noise of the same level. Approximately 5% were exposed to road and aircraft noise combined.

2.4 Hypertension was identified in 25% of the study sample, the majority of which were due to self-reported doctor’s diagnoses. The average 5-year aircraft noise exposure prior to an event was associated with an increased risk of hypertension per 10 dB increase in noise (HR 1.16; 95 % CI 1.08-1.24[1]), but there were no associations for road traffic or railway noise. However, the risk appeared particularly high among those exposed to both aircraft and road traffic noise (HR 1.39; 95 %CI 1.14-1.70). The authors adjusted the data for confounders such as gender, education, physical activity, family history etc and further adjustments for diet, alcohol consumption, socioeconomic status. Air pollution from oxides of nitrogen (NOx) did not alter the results. When restricted to just those people living at the same address for the duration of the study, the results remained unchanged.

2.5 The recent WHO review on environmental noise and cardiovascular and metabolic effects has suggested that there is a degree of uncertainty in the current evidence for a hypertension effect, which remains inconclusive due to a

[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.

lack of longitudinal studies. The authors of this study propose that these results go some way in addressing this knowledge gap.

2.6 A study by Imperial College, London was authored by Naim et al and investigated the relationship between indoor and outdoor noise in residential exposure to aircraft, railway and road noise. This study explored the variability of the relationship between indoor and outdoor noise at 49 residential dwellings in London. The rationale for this was that most studies use modelled outdoor noise estimates when investigating the link between noise exposure and health, and these authors wished to explore the potential for misclassification or bias. The study involved continuous noise measurement for three days both inside and outside, using noise monitors. The homes were located close to major roads, railways, under an aircraft flight path or a combination of these, and most of the measurements were taken during winter months.

2.7 Mean indoor noise was lower than the outdoor noise and lower for night-time compared to daytime in this study. The mean noise levels recorded were 38.4 dB indoors and 57.7 dB outdoors for LAeq,16h and 30.2 dB indoors and 52.1 outdoors for Lnight. Linear regression revealed that there was a strong association between indoor and outdoor noise levels, and that Lnight was a better predictor of this than LAeq, 16h. The authors suggest that in future epidemiological studies, using the Lnight metric will provide a less biased measure of exposure than the daytime noise metric.

2.8 Heyes et al from Manchester Metropolitan University presented a European review of aircraft noise mitigation strategies with respect to industry stakeholders' perspectives and opinions. The paper presents the findings of a series of stakeholder interviews with aviation noise stakeholders to determine the efficacy of current noise management approaches, and to identify ways in which noise could be better managed in the future. The research is part of ANIMA (Aviation Noise Impact Management through novel Approaches) which is a Horizon 2020 funded study, that has been undertaken to better understand noise impact mitigation in the EU, with the aim of developing new methodologies, approaches and tools to manage and mitigate the impact of aviation noise.

2.9 The stakeholder groups invited to participate were:

- Airlines
- Airports
- Aviation Authorities (i.e. European Bodies and national Civil Aviation Authorities)
- Community Groups
- Consultancies

• Freight Organisations

• Local Authorities

• Research Centres

2.10 20 individuals participated in the research, which took place over winter 2017/2018. The questionnaires took approximately 1-2 hours and covered a range of topics such as:

- General perceptions and opinions regarding aviation noise.
- Noise policy and its efficacy.
- Application of the ICAO Balanced Approach (a four-element concept based on “reduction of noise at source”, “noise abatement procedures”, “land-use planning” and “operational restrictions”) and the effectiveness of its different elements.
- Noise Impact Management, including a consideration of non-acoustic factors, and issues such as quality of life and the value of complaints in understanding noise impact.

2.11 As expected, the responses varied between parties, and examples of individual responses can be found in the paper, but some common themes emerged.

1. Aviation noise was cited as remaining the significant environmental issue to airport communities, and the biggest constraint to airport developments.
2. Of the four Balanced Approach elements, Land Use Planning was highlighted as the biggest failure in that airports are not given enough protection from encroachment, as local authorities look to grow.
3. In general, participants felt that the Environmental Noise Directive provided a useful way for noise to be compared across different airports and Member States, but that the metrics used to monitor noise were not appropriate for the public to understand, or effectively capture the impacts of noise.
4. There is a call for more research on annoyance and noise, for example what are the specific factors of noise that increase annoyance, and what are the links between annoyance and the known health impacts of noise impact? Likewise, better understanding the quality of life of local communities was also raised as an important future research field in terms of the positive and negative impacts of living near to an airport, and how airports can do more to improve quality of life.
5. There was a consensus for more research into understanding the efficacy of interventions made by airports to reduce noise impact and annoyance, and to improve quality of life. Airports particularly noted that they often do not know if

what they are doing will prove effective, but are driven to do so by political pressure.

2.12 Bartalucci et al produced a paper from the University of Florence, that describes a new methodology for assessing schoolchildren's exposure to aircraft noise within classroom environments. The paper discusses the methodologies used in the RANCH and NORAH studies, and the research gaps in this area as identified by the ENNAH (European Network on Noise and Health), namely:

- A requirement to improve the accuracy of exposure-response curves and update them by conducting further studies, given the annoyance response to aircraft noise has increased in recent years;
- The need to assess specific exposure-response curves for children;
- The need to study the long-term consequences of exposure to aircraft noise of children during school hours.

2.13 The University of Florence has developed a methodology that enables the aircraft noise to be synchronised with the tests being administered to the children in real-time, whilst taking into account the acoustic properties of the building such as insulation and reverberation. In summary, the design incorporates three elements:

1. The design of an electro-acoustic system and an on-site listening laboratory to be considered equivalent to a classroom located near the take-off/landing paths of the airport;
2. The processing of audio signals capable of reproducing the take-off movements of the aircrafts in open and closed window conditions, also representing different environmental configurations or windows with a different sound insulation, which can be run concurrently with the questionnaires;
3. The possibility to reproduce the aircraft noise events in specific moments during the reading test that the children are completing.

2.14 The aim of the methodology is to allow different combinations of aircraft noise exposure and environmental conditions (open/closed windows) to be played to the children as they complete the tests assigned to them, with a view to the data assisting in the development of more accurate dose-response relationship curves.

2.15 The methodology has been used in two schools, one that regularly experiences aircraft noise and one that does not. The authors aim to compare the results of the reading tests between the two samples of pupils, to examine how aircraft noise influences performance in those habituated to noise, and those pupils who are not used to hearing it.

2.16 Dirk Schreckenberg presented a paper on the knowledge gaps that exist in the health impacts of environmental noise. The author discusses recent work such as the NORAH and SiRENE studies and provides an overview and discussion of the remaining gaps in knowledge. He proposes the need for a comprehensive noise impact model on health and explains the widely accepted stress model proposed by Babisch in which he describes the link between noise and cardiovascular disease and risk factors (mediators) that occur in between. In this scheme disturbances (e.g. sleep disturbances), stress indicators (e.g. stress hormone releases), risk factors (e.g. blood pressure) and manifest diseases (e.g. hypertension, ischaemic heart diseases) are distinguished. Schreckenberg explains that the advantage of this model is that it provides a biological overview about relevant factors in the casual chain from environmental noise to cardiovascular diseases. However, he states that the general stress model is not specific enough for verifiable predictions, and to describe the bio-psycho-social complexity of the impact of noise on human beings. It is still the case that the psycho-physiological pathways from noise exposure to long-term health effects and the interrelationship between mediating responses, context factors and different health outcomes are not yet properly understood. The author cites the example of how annoyance judgements include sleep disturbances, or vice versa.

2.17 The interrelationships between noise exposure, noise effects and potential mediators are unclear, which is an important issue for noise policy. A given example is in noise abatement. If the relationships between annoyance and other health outcomes are more fully understood, strategies aiming to reduce annoyance by means of the management of acoustic and non-acoustic context-related factors would also improve further mental and physical health outcomes.

2.18 Schreckenberg also explains that if there was a better understanding of the non-acoustic, contextual impact factors on noise responses, what they have in common and at what stage of the noise stress processing they affect the response, these factors could be given more attention to in noise control management.

2.19 The author describes the knowledge gaps that remain since the publication of the final ENNAH report in 2013, which also detailed gaps in knowledge and suggestions for further research at that time. The WHO evidence reviews that were conducted as part of the new European Noise Guidelines (published in October 2018) discussed several remaining knowledge gaps, which refer to:

- study design

there is a need for longitudinal and retrospective studies. This is particularly important for studies on mental health, cognition, and hearing loss.

- noise exposure assessment

a need for the individual's noise dose, the assessment should include the exposure during the individuals' different whereabouts for 24 hours (at home, workplace, leisure time etc.) A discussion about the use of supplementary metrics such as Number Above in addition to average noise levels such as LAeq is ongoing. There are also knowledge gaps in understanding the way in which different noise sources impact effects on health, and the context in which the outcomes are induced for each noise source. Similarly, the health effects of combined noise sources are not fully understood.

- populations and life course approaches

- confounding factors and effect modification

Knowledge gaps exist concerning confounding factors and effect modification such as combined effects of air pollution and noise on health. It is suggested that the different causal pathways of noise and air pollution to health outcomes should be investigated in future studies.

- health outcomes

- interventions.

2.20 Whilst studies exist on reducing the noise at source, research into the impacts to health on such noise reduction and interventions is lacking. It is recommended that future studies should be of high quality, following a standardised protocol for a before-after study design that facilitates study comparability and considers both short- and long-term health effects.

2.21 Guski et al presented a paper on present exposure response relationships for aircraft noise annoyance. The report examines the results from 19 aircraft noise studies conducted between 2001-2015 (including SoNA 2014) and explores the possible reasons for the differences in their exposure-response relationships.

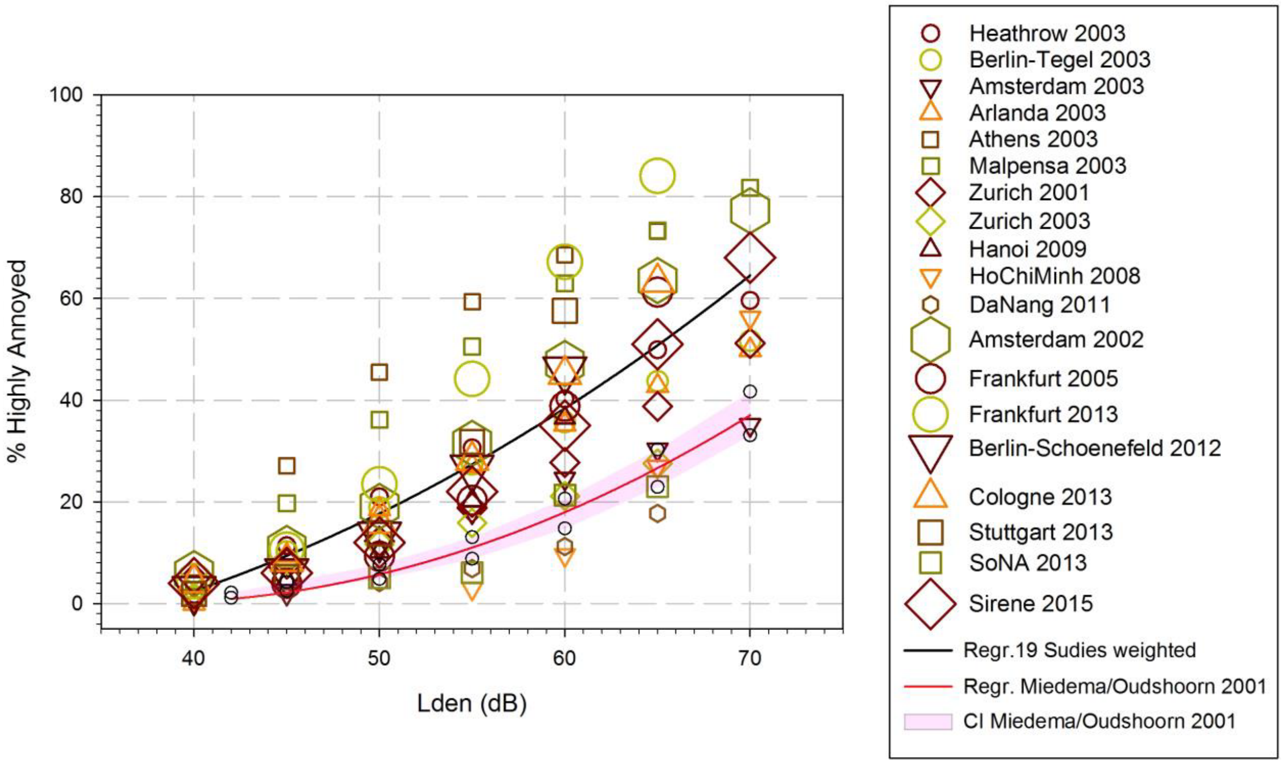

Figure 1: Exposure-response relations for %HA and Lden from 19 aircraft noise surveys performed 2001-2015. The size of the symbols corresponds to the respective study sample size. The black and red curves both show quadratic regressions: the black curve relates to the new dataset; the red curve relates to the Miedema/Oudshoorn analysis. Reproduced from the Euronoise proceedings, 2018.

2.22 Guski et al state that Figure 1 illustrates that most of the data points sit above the original EU curve for %HA. There is ongoing discussion regarding the possible reasons for this, and no conclusive answers, but the factors often raised to explain the difference include:

1. methodological differences between studies (e.g. sound calculation methods, response rate and participant selection, answer formats);

2. situational or contextual differences between studies (e.g. change-rate of the airport, changes in the composition of the aircraft fleet);

3. societal changes (e.g. changes in the health-related values shared by a society).

2.23 The differences in methodology that have been observed over the years, such as the type of contact with the respondent (postal, face to face, telephone), response rate (being higher in previous years) and the type of annoyance scale used (reflecting a change from four or five-point scales, to the standardised 11-

point scale used today). Differences in sampling strategies and the methods for estimating the dose of aircraft noise in older versus more recent studies are also discussed.

2.24 In relation to situational differences, the notion of ‘high rate of change’ (HRC) and ‘low rate of change’ (LRC) airports has been introduced in recent years to reflect whether there are any plans for expansion or not. In 2015 Janssen & Guski proposed “to call airports 'low-rate change (LRC) airports', as long as there is no indication of a sustained abrupt change of aircraft movements, or the published intention of the airport to change the number of movements within 3 years before and after the study. An abrupt change is defined here as a significant deviation in the trend of aircraft movements from the trend typical for the airport. Each trend is calculated by means of total movement data during a five-year period. If the typical trend is disrupted significantly and permanent, it is called a 'high-rate change (HRC) airport'. This is also the case if there has been public discussion about operational plans within 3 years before and after the study."

2.25 The comparison between the black and red curves in Figure 2 shows higher %HA for HRC situations compared to LRC airports at comparable Lden levels. The authors point out that even the LRC curve is higher than the EU-standard and explain that there is a certain confounding of HRC/LRC and “large study/small study” sample sizes. The set of LRC studies comprises 15,792 participants, i.e., an average of 1,745.7 participants per study, and the set of HRC studies comprises 22,764 participants, i.e., an average of 2,529.3 participants per study. The studies are weighted according to sample size in Figures 1 and 2, which means that the exposure-response relationship of the total dataset (Figure1) may be somewhat biased due to the influence of (mostly large) HRC studies.

2.26 In terms of societal changes, noise sensitivity is often cited as a potential factor that may contribute to an increase in annoyance response. Although there is no evidence to suggest that noise sensitivity has increased over the years, the authors suggest that people have become more attentive to environmental dangers to their individual health and well-being.

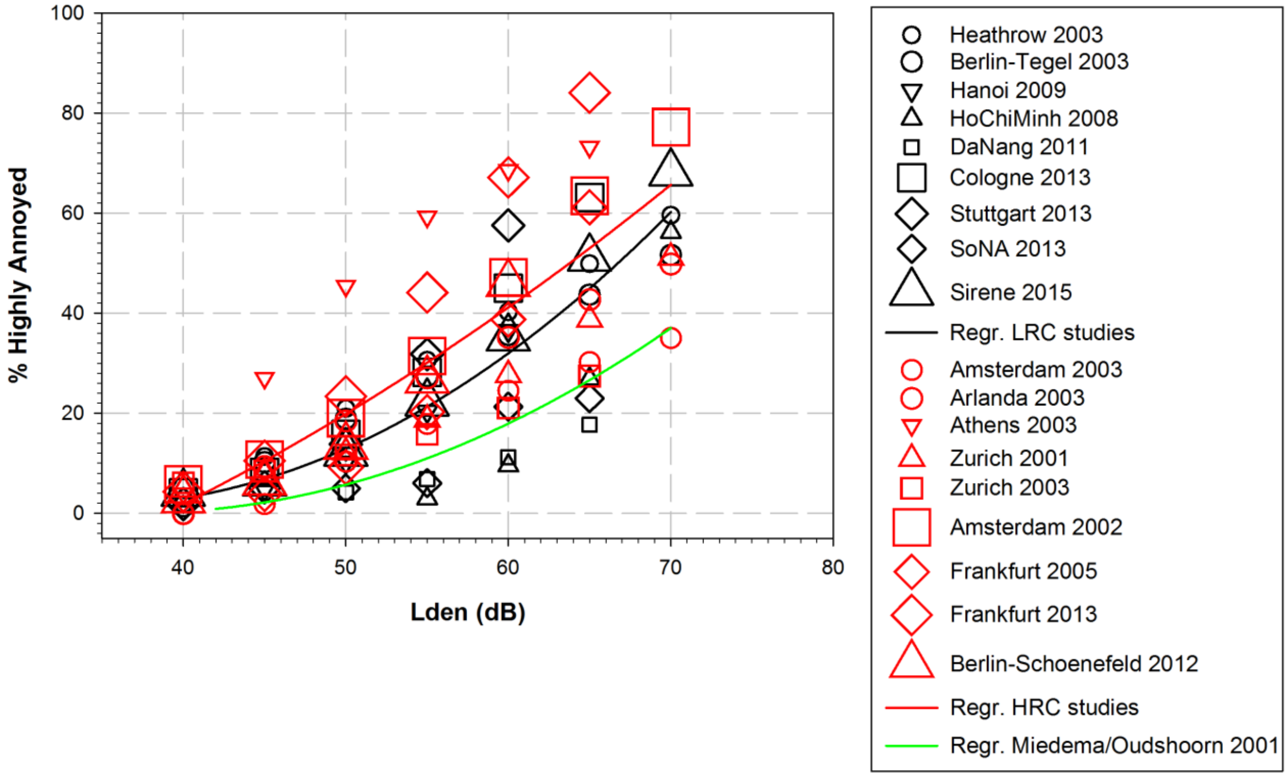

Figure 2. Exposure-response data form %HA and Lden from 9 HRC studies. The black curve represents the quadratic fit for LCR studies, the red curve represents the quadratic fit for HRC studies. For comparison, the general EU standard curve is shown (green). Reproduced from the Euronoise proceedings, 2018.

Chapter 3

Internoise Findings

3.1 The Internoise Congress was held in Chicago at the end of August 2018 and the proceedings have been reviewed for papers relevant to aircraft noise and health.

3.2 These included a keynote presentation by Truls Gjestland, who gave an overview of the history of aircraft noise annoyance research, the pros and cons of current methodologies and suggestions for future ways in which to form exposure-response curves. He argues that noise-induced annoyance depends on a variety of survey-specific, non-acoustic factors that move dose-response curves back and forth or up or down. Gjestland cites work by Basner et al (2017) which found that noise exposure alone accounts for only about a third of the variance of individual responses. He suggests that since the combined influence of these non-acoustic factors varies from one airport community to the next, it may be futile to seek a single function that accurately describes the relationship between noise exposure and prevalence of annoyance in all airport communities.

3.3 Gjestland suggests that using the Community Tolerance Level (CTL) developed by Fidell (2011) is a more appropriate method of obtaining dose-response relationships for aircraft noise annoyance. CTL analysis treats the proportion of a community that describes itself as highly annoyed as equally influenced 1) by noise exposure, and 2) by a non-acoustic criterion for self-reporting of annoyance. The growth of annoyance with noise exposure follows the effective loudness function, but the "starting point" on the axis of the response curve is determined by non-acoustic factors. Gjestland argues that the effect of these factors is a real change in noise-induced annoyance, not just an "additional annoyance" caused by other factors.

3.4 The Community Tolerance Level is defined as the value of the noise exposure, DNL, at which 50 percent of the population describes itself as highly annoyed. Each community is treated separately in CTL analysis and characterised by a single value. Gjestland presents re-analyses of 63 surveys between 1961 and 2017 using this method. He also demonstrates the importance of the type of airport (HRC versus LRC) in terms of the impact on annoyance.

3.5 The annoyance question was also examined. Until 2001 different questions and scales were used to measure the annoyance response to aircraft noise. In 2001 Fields et al. proposed a standardised way of conducting community noise surveys. They recommended that two standardised questions should be included in future surveys to assist inter-survey comparisons. These are now ISO standards and have been used in surveys since then. To examine this, a sample of 18 studies post 2000 were also included in Gjestland's meta-analysis, alongside Guski's analysis of 12 selected post-2000 surveys.

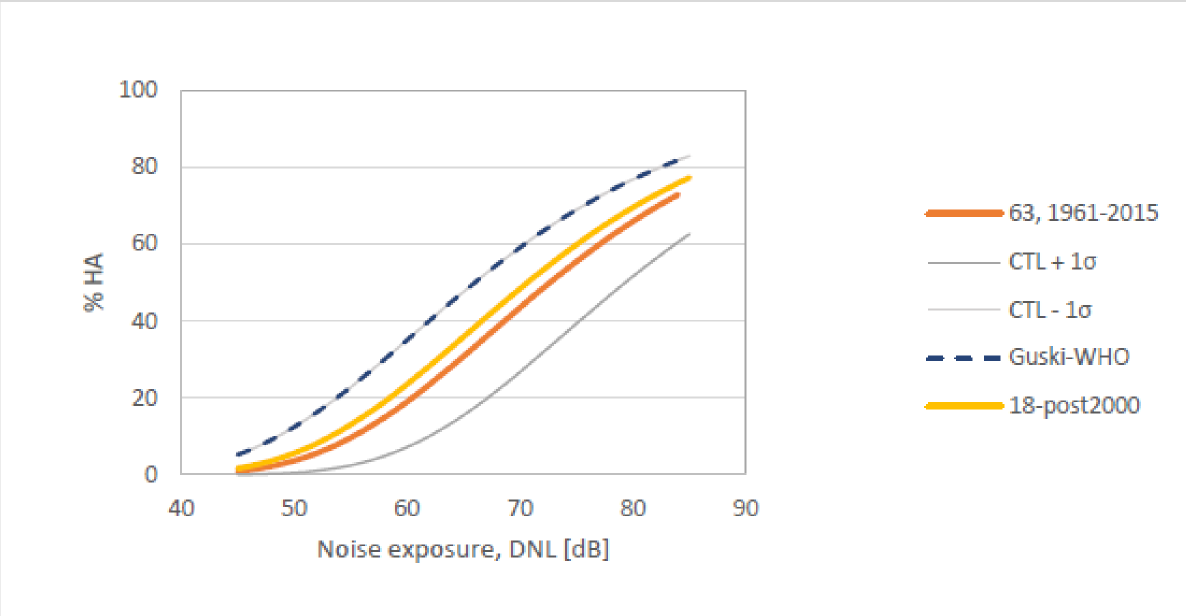

Figure 3: Average dose-response curves for 63 surveys, 1961-2015, for a selection of 18 post-2000 surveys, and for a selection of 12 post-2000 surveys made by Guski et al. (2017). Reproduced from Internoise proceedings 2018.

3.6 Gjestland explains that some analyses have been confounded by different distributions of non-acoustic factors such as HRC and LRC airports. More studies are conducted at HRC airports in recent years, which has the effect of appearing as though more people are more highly annoyed. He argues that when examined under the same conditions, people today appear to show the same degree of annoyance from aircraft noise as they did 50 years ago.

3.7 Figure 3 shows the average dose-response curve for 63 aircraft noise surveys conducted between 1961 and 2015 and a similar curve for 18 post-2000 studies. The total data set comprises about 27 % HRC studies and the post-2000 data set comprises 50 % HRC studies. The analysis by Guski et al. (2017) is also shown, which contains 63 – 80 % HRC studies (depending on definition). Figure 3 illustrates that as the percentage of HRC studies increases, the dose-response curve is shifted towards higher annoyance. However, even the results from the Guski analysis is within the 1σ interval for the complete data set. Gjestland concludes that the CTL method successfully includes not only the actual noise level, but a variety of non-acoustic factors which can vary between communities.

3.8 Eagen et al published findings regarding aircraft noise conditions affecting classroom behaviours in 11 schools situated around Los Angeles International airport. The study examined the relationship between the behaviours and attitudes of students and teachers compared with internal and external noise levels. Observers in individual classrooms logged student and teacher behaviours. Noise levels were assessed through direct measurements outside the schools and within the classrooms simultaneous to the classroom observations (acute) and using computer modelling of long-term (chronic) school-day noise exposure. Additionally, teachers reported their attitudes and experiences related to aircraft noise exposure through an online survey.

3.9 Observations were made via an electronic tablet, with one observer watching the teacher for the entire session, and another observer watching the children one at a time in two-minute periods.

3.10 Interestingly, there were no observed aircraft noise-related distractions on any day of the study period. The overall percentage of observed student distractions due to other transportation noise was also very low, less than 1%. The authors suggest this may be due to the observation method of each student only being observed for a two-minute period.

3.11 Teachers were observed for voice-masking due to aircraft noise, or voice-raising to make themselves more audible. The findings suggest that it may be that the number of noise events, rather than the time spent above a certain noise threshold, is more important for teaching voice-masking events. No teacher voice-raising events were observed in 63% of the sessions, one event was observed in 14% of the sessions, two or more events were observed in 23% of the sessions. The internal Time Above and internal Number Above were both associated with voice-raising events, yet for the external noise metrics only external NA and not external TA showed associations with voice-raising events. The authors explain that these findings suggest the importance of internal noise for voice-raising events, and also suggest that in terms of external noise that the number of events may be more important than the time above.

3.12 The teachers were asked about aircraft noise annoyance when teaching. Almost two-thirds of the respondents reported not being annoyed by aircraft noise at all when teaching; however, 25% of respondents reported being slightly, moderately, or very annoyed by aircraft noise when teaching. The authors found that teachers from schools that were exposed to 55 dBA external LAeq or higher from aircraft were seven times more likely to report aircraft noise annoyance at school than teachers from schools exposed to less than 50 dBA external LAeq from aircraft.

3.13 Porter et al presented a research road map for aircraft noise around Heathrow airport, building on research knowledge gaps with the aim of contributing to the international research agenda, and engaging with/and improving the quality of life in communities around the airport.

3.14 A research roadmap has been developed by Heathrow, working with the ACI EUROPE Noise Task Force. In addition, Heathrow also co-ordinated a number of workshop meetings during 2015/6 on future research priorities to review the state of knowledge on research into health and quality of life related to aircraft noise, and to identify knowledge gaps. The draft roadmap is shown in Figure 4.

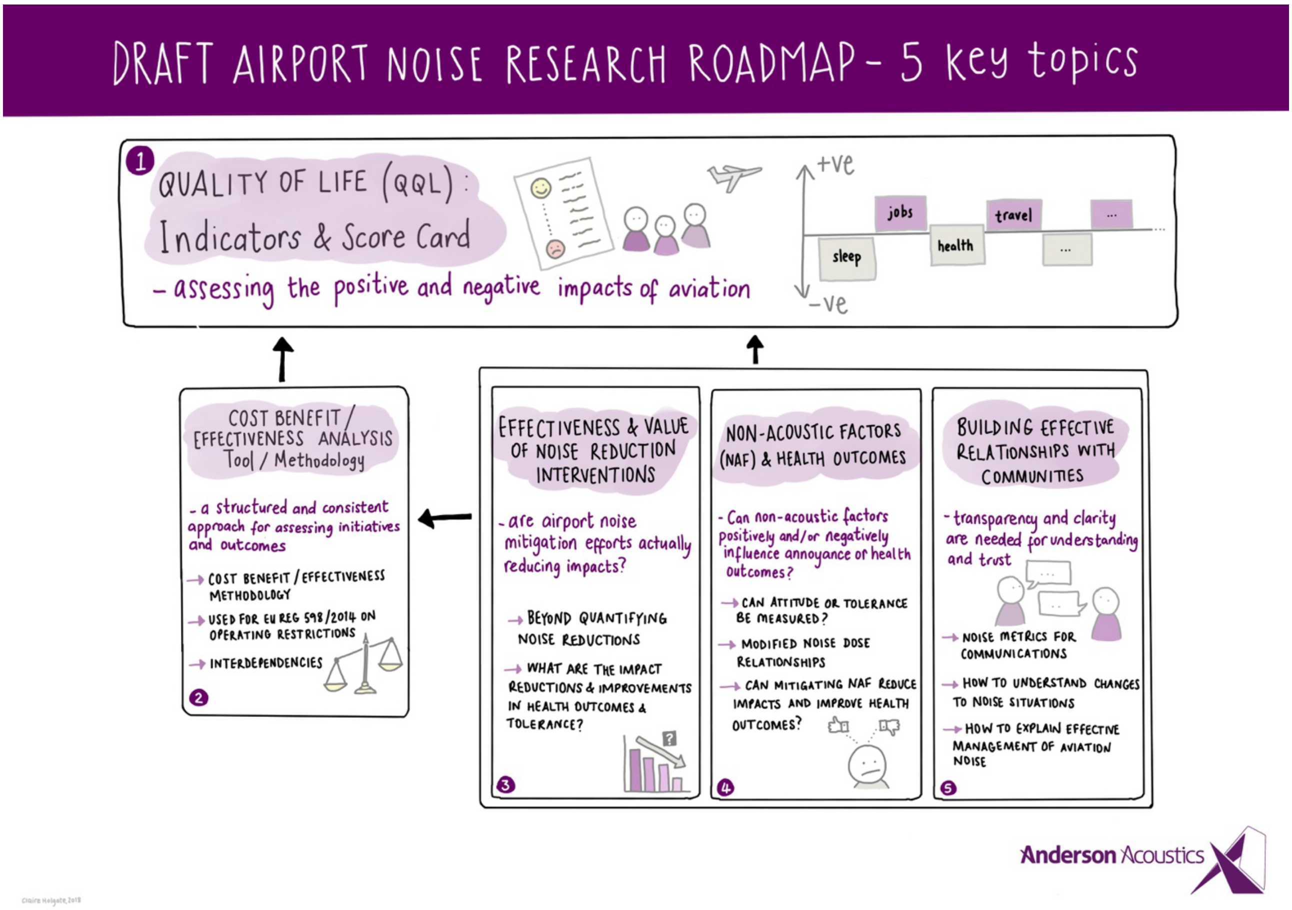

Figure 4: Draft Research Roadmap for Heathrow airport. Taken from Internoise proceedings.

3.15 There is a need for agreed consensus on what indicators (positive and negative) can be balanced to achieve improved quality of life for communities. There is also a requirement for cost benefit/effectiveness analysis that enables a consistent approach for assessing outcomes in terms of the impacts of aviation. In line with this, the authors argue there is a need for increased understanding of the value and effectiveness of the interventions made by airports. There also needs to be an improved understanding of the relationship between non-acoustic factors and health outcomes and how these could be managed in order to reduce the health effects of aircraft noise. Finally, airports need to improve their relationships with communities in order to better explain aircraft noise through increased transparency and more clear explanations of any changes in the noise dose.

3.16 Baudin et al reported results that were found as part of the French DEBATS (Discussion on the health effects of aircraft noise) study, which included 1,244 residents around three major French airports (Paris-Charles de Gaulle, Lyon-Saint-Exupéry and Toulouse-Blagnac). One of the objectives of the study was to evaluate the effects of annoyance due to aircraft noise on psychological distress in people living near airports in France. Aircraft annoyance was assessed using the ICBEN 5-point scale of annoyance, and psychological distress was measured using the 12-point General Health Questionnaire (GHQ). Noise sensitivity was also included in the analysis.

3.17 A significant association was found between annoyance due to aircraft noise and psychological distress: Odds Ratios ranged from 1.49 (95% CI 0.94-2.39) to 3.64 (95% CI 1.70-7.78), with gradual ORs increasing across the different categories of annoyance. The results remained similar when noise sensitivity was included in the model. People reporting to be more sensitive than people around them had a higher risk of psychological distress (OR=1.70, 95% CI 1.25-2.31).

3.18 The authors cautioned that the direction of the association between aircraft noise-induced annoyance psychological distress is not fully understood. They explain that extremely annoyed people may be at a greater risk of psychological disorders, but it is also the case that people with psychological disorders may be more predisposed to being annoyed. It is suggested that further research into the direction of this association is required.

3.19 Nassur et al presented the findings of a study, subsequently published as a paper, into aircraft noise and sleep quality in populations living around airports in France. The 112 participants were also part of the DEBATS study, and were living around Paris Charles de Gaulle, or Toulouse-Blagnac airports. The participants wore actimeters on their wrists for eight nights in order to obtain data relating to sleep quality in terms of total sleep time (TST), sleep onset latency (SOL), wake after sleep onset (WASO) and sleep efficiency (SE). Noise measurements were taken inside and outside (at the façade) the participants' bedroom. Estimations of LAeq for inside of the bedroom and outside the dwelling were made, along with the number of aircraft noise events.

3.20 The results indicated that increased levels or numbers of aircraft noise events were associated with increased SOL and total WASO, and decreased SE. Interestingly, in this study a significant association was found between an increase in aircraft noise and TST, with participants experiencing an increase in TST, rather than the expected decrease. The authors suggest that this may be due to an adaptation behaviour to sleep deprivation, with those people who are exposed to higher levels of aircraft noise choosing to stay in bed longer to compensate for a decrease in sleep quality during the night. The authors also argue for the inclusion of a number of events metric in such studies going forward.

Chapter 4

WHO Guidelines

Introduction and background

4.1 This chapter provides a brief overview of the recommendations made in the new WHO guidelines for road, rail and aircraft noise. These Guidelines are for the European region and have been informed by a series of systematic literature reviews on each of the health outcomes concerned. The aircraft noise and annoyance review was authored by Guski et al and will be referred to in more detail later in this chapter. Since publication of the Guidelines, a critique of the methods used to determine the recommended noise limits for annoyance has been published by Gjestland, which will also be discussed.

4.2 In 2010 the WHO was requested by Member States in the European Region to produce updated guidelines to their previously published Guidelines (1999 for annoyance, and 2009 for night noise). It was decided that alongside transportation noise, they should also include other noise sources that had not previously been formally considered such as electronic devices, wind turbines and toys.

4.3 The WHO Regional Office for Europe therefore developed environmental noise guidelines for the European Region, proposing an updated set of public health recommendations on exposure to environmental noise.

4.4 The main purpose of the guidelines is to provide recommendations for protecting human health from exposure to environmental noise originating from various sources: transportation (road traffic, railway and aircraft) noise, wind turbine noise and leisure noise.

4.5 The following two key questions identified the issues addressed by the guidelines.

- In the general population exposed to environmental noise, what is the exposure–response relationship between exposure to environmental noise (reported as various indicators) and the proportion of people with a validated measure of health outcome, when adjusted for confounders?
- In the general population exposed to environmental noise, are interventions effective in reducing exposure to and/or health outcomes from environmental noise?

4.6 The Guidelines were formulated as a result of expert subject groups using the GRADE system (Grading of Recommendations Assessment, Development and Evaluation) in order to address specific questions within each area.

4.7 The GRADE interpretations of quality of evidence are:

- High quality: further research is very unlikely to change the certainty of the effect estimate
- Moderate quality: further research is likely to have an important impact on the certainty of the effect estimate and may change the estimate
- Low quality: further research is very likely to have an important impact on the certainty of the effect estimate and is likely to change the estimate
- Very low quality: any effect estimate is uncertain

4.8 The different steps in the development of the guidelines included:

- formulation of the scope and key questions of the guidelines;
- review of the pertinent literature;
- selection of priority health outcome measures;
- a systematic review of the evidence;
- assessment of certainty of the bodies of evidence resulting from systematic reviews;
- identification of guideline exposure levels; and
- setting of the strength of recommendations.

Systematic Reviews

4.9 The paper on environmental noise and annoyance included systematic literature reviews and meta-analyses of data collected in road traffic, aircraft, railway and wind turbine noise studies between 2000 and 2014. The main objectives of the systematic reviews were to assess the strength of association between exposure to environmental noise and long-term noise annoyance based on field research reported, to quantify the increase of annoyance with an incremental increase in noise exposure, and to present an exposure-response relation for each noise source.

4.10 Annoyance, in relation to environmental noise, is often retrospective when given as part of a survey response, and is defined as:

- an often-repeated disturbance due to noise (repeated disturbance of intended activities, e.g., communicating with other persons, listening to music or watching TV, reading, working, sleeping), and often combined with behavioural responses in order to minimise disturbances;
- an emotional/attitudinal response (anger about the exposure and negative evaluation of the noise source); and
- a cognitive response (e.g., the distressful insight that one cannot do much against this unwanted situation).

4.11 The noise annoyance response considered here is related to long-term exposure, i.e., related to residents who live in a high or low noise area for at least one year and answer noise annoyance questions related to a long period of time. The participants of the included studies were selected according to specified procedures and answered at least one standardised noise annoyance question (ICBEN scale and ISO recommended scale).

4.12 As part of the systematic reviews, only studies that met the following criteria were included:

1. Study type: cross-sectional or longitudinal surveys, using an explicit protocol for selecting respondents.

2. Participants: Studies including members of the general population (mainly residents of noise-exposed areas).

3. Exposure type: Long-term outside noise levels which are either expressed in LAeq,24h, Ldn, Lden or its components (Lday, Levening, Lnight and the duration in hours of night, or can be easily converted from similar acoustic variables.

4. Outcome measure: The base of the outcome measure is the individual annoyance response made during a standardised survey. The annoyance question and the response format either follow the recommendations given by ICBEN and/or ISO directly, or are very close to them.

5. Confounders: Papers containing a potential second risk factor besides noise (e.g., vibrations in case of railway noise close to the tracks)

6. Language: Papers in English, French, Dutch, and German were included as long as they met the selection criteria.

4.13 Following the criteria resulted in a list of 34 annoyance papers containing 62 individual studies that could possibly be used in the evidence review for all noise sources.

4.14 Data from 15 aircraft noise annoyance surveys around national and international airports were collected from publications and authors' questionnaires. For 12 of the 15 aircraft noise studies, exposure-response functions of the relationship between Lden and modelled %HA were available, aggregating data from 17,094 study participants.

4.15 In total, eight systematic reviews of evidence were conducted to assess the relationship between environmental noise and the following health outcomes: cardiovascular and metabolic effects; annoyance; effects on sleep; cognitive impairment; hearing impairment and tinnitus; adverse birth outcomes; and quality of life, mental health and wellbeing.

4.16 A separate systematic review of evidence was conducted to assess the effectiveness of environmental noise interventions in reducing exposure and associated impacts on health. The systematic reviews have been presented at various Congresses such as Internoise and Euronoise this year, and in part at ICBEN in 2017. The reviews detail the meta-analyses used to obtain the strength of evidence for each outcome and any knowledge gaps that currently exist.

4.17 The strength of the recommendations is classed as either 'strong' or 'conditional'.

- A strong recommendation can be adopted as policy in most situations. The guideline is based on the confidence that the desirable effects of adherence to the recommendation outweigh the undesirable consequences. The quality of evidence for a net benefit – combined with information about the values, preferences and resources – inform this recommendation, which should be implemented in most circumstances.
- A conditional recommendation requires a policy-making process with substantial debate and involvement of various stakeholders. There is less certainty of its efficacy owing to lower quality of evidence of a net benefit, opposing values and preferences of individuals and populations affected or the high resource implications of the recommendation, meaning there may be circumstances or settings in which it will not apply.

The Findings

4.18 One of the main outcomes of the systematic review are updated dose response functions, for aircraft noise, the key ones being the dose response function for annoyance as a function of Lden and sleep disturbance versus Lnight. The corresponding estimated data points for each of the 12 studies (called the WHO full dataset) are plotted in Figure 5, together with the estimated exposure-response relationship for the aggregated data (black line).

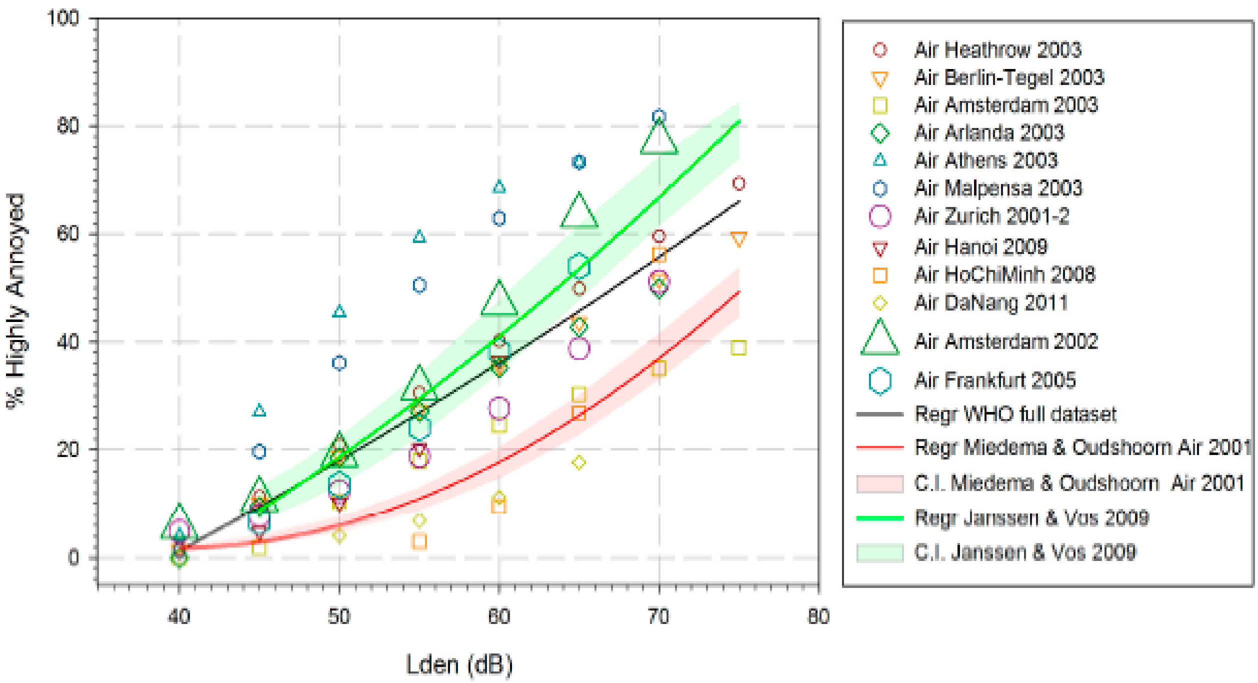

Figure 5: Scatterplot and quadratic regression of the relation between Lden and the calculated %HA for 12 aircraft noise studies (black), together with exposure-response functions by Miedema and Oudshoorn (red), and Janssen and Vos (green).

4.19 From the 12 studies of the WHO aircraft dataset, five airports were considered as “low-rate change” (if there is no indication of a sustained abrupt change of aircraft movements, or the published intention of the airport to change the number of movements within three years before and after the annoyance study): Heathrow 2003, Tegel 2003, Hanoi 2009, Ho Chi Minh 2008, and Da Nang 2011. Another five airports were considered to be “high-rate change” airports (a significant deviation in the trend of aircraft movements from the typical trend for the airport, or if there has been public discussion about operational plans within three years before and after the study): Arlanda 2003, Athens 2003, Amsterdam 2002, Amsterdam 2003, and Frankfurt 2005. The exposure-response relationships for these two groups are illustrated in Figure 6.

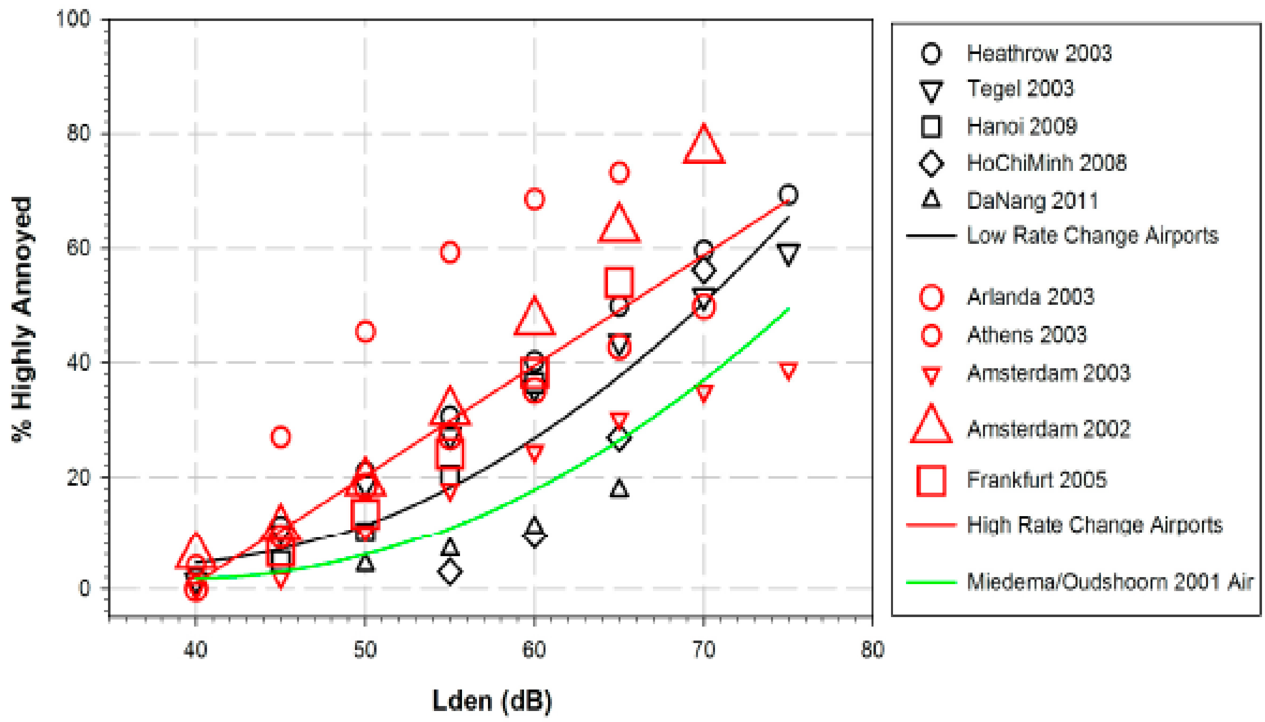

Figure 6: Scatterplot and regression lines of the relationship between Lden and the calculated HA% for five "high rate of change" (red curve) and five "low-rate change" (black curve) airport noise studies, together with exposure-response function by Miedema and Oudshoorn (green).

4.20 The authors of this review support the idea of a slight general aircraft noise annoyance trend even at low-rate change airports, and a considerably higher increase of aircraft noise annoyance at high-rate change airports. The differences between high rate change and low rate change have been highlighted by Guski et al, but appear to have been ignored in the new Guidelines, a point which has been stressed by Gjestland.

4.21 The cardiovascular guideline level is 52dB Lden for IHD, so well above the annoyance guideline level of 45dB Lden. Therefore, the annoyance guideline more than achieves the cardiovascular outcome.

Recommendations

Road traffic noise

4.22 For average noise exposure, the Guideline Development Group (GDG) strongly recommends reducing noise levels produced by road traffic below 53 decibels (dB) Lden, as road traffic noise above this level is associated with adverse health effects.

4.23 For night noise exposure, the GDG strongly recommends reducing noise levels produced by road traffic during night time below 45 dB Lnight, as night-time road traffic noise above this level is associated with adverse effects on sleep.

4.24 To reduce health effects, the GDG strongly recommends that policymakers implement suitable measures to reduce noise exposure from road traffic in the population exposed to levels above the guideline values for average and night noise exposure. For specific interventions, the GDG recommends reducing noise both at the source and on the route between the source and the affected population by changes in infrastructure.

Railway Noise

4.25 For average noise exposure, the GDG strongly recommends reducing noise levels produced by railway traffic below 54 dB Lden, as railway noise above this level is associated with adverse health effects.

4.26 For night noise exposure, the GDG strongly recommends reducing noise levels produced by railway traffic during night time below 44 dB Lnight, as railway noise above this level is associated with adverse effects on sleep.

4.27 To reduce health effects, the GDG strongly recommends that policy-makers implement suitable measures to reduce noise exposure from railways in the population exposed to levels above the guideline values for average and night noise exposure. There is, however, insufficient evidence to recommend one type of intervention over another.

Aircraft Noise

4.28 For average noise exposure, the GDG strongly recommends reducing noise levels produced by aircraft below 45 dB Lden, as aircraft noise above this level is associated with adverse health effects.

4.29 For night noise exposure, the GDG strongly recommends reducing noise levels produced by aircraft during night time below 40 dB Lnight, as aircraft noise above this level is associated with adverse effects on sleep.

4.30 To reduce health effects, the GDG strongly recommends that policy-makers implement suitable measures to reduce noise exposure from aircraft in the population exposed to levels above the guideline values for average and night noise exposure. For specific interventions the GDG recommends implementing suitable changes in infrastructure.

4.31 Table 1 shows the summary of findings for health effects from exposure to aircraft noise using the Lden metric. Table 2 shows the same for sleep disturbance and Lnight.

Noise metric	Priority health outcome measure	Quantitative risk for adverse health	Lowest level of exposure across studies	Number of participants (studies)[a]	Quality of evidence
Cardiovascular disease					
L_{den}	Incidence of IHD	RR = 1.09 (95% CI: 1.04–1.15) per 10 dB increase	47 dB	9 619 082[a] (2)	Very low (downgraded for risk of bias; upgraded for dose-response)
L_{den}	Incidence of hypertension	RR = 1.00 (95% CI: 0.77–1.30) per 10 dB increase	N/A	4712 (1)	Low (downgraded for risk of bias and because only one study available)
Annoyance					
L_{den}	%HA	OR = 4.78 (95% CI: 2.27–10.05) per 10 dB increase	33 dB	17 094 (12)	Moderate (downgraded for inconsistency)
Cognitive impairment					
L_{den}	Reading and oral comprehension	1–2-month delay per 5 dB increase	Around 55 dB	(4)	Moderate (downgraded for inconsistency)
Hearing impairment and tinnitus					
L_{den}	Permanent hearing impairment	–	–	–	–

Note: [a] Results are partly derived from population-based studies.

Table 1: Summary of findings for health effects from exposure to aircraft noise (Lden)

Noise metric	Priority health outcome measure	Quantitative risk for adverse health	Lowest level of exposure across studies	Number of participants (studies)	Quality of evidence
Effects on sleep					
L_{night}	%HSD	OR: 1.94 (95% CI: 1.61–2.33) per 10 dB increase	35 dB	6371 (6)	Moderate (downgraded for study limitations, inconsistency; upgraded for dose-response, magnitude of effect)

Table 2: Summary of findings for health effects from exposure to aircraft noise (Lnight)

4.32 It should be noted that as there are fewer flights at night, more people are exposed to 45dB Lden than 40dB Lnight around most airports, therefore the limiting guideline is normally the annoyance guideline, not the night-time guideline, despite the limit being 5dB lower. To put this into context, in 2016 around Heathrow it is estimated that there were around six million people who were exposed to at least 45dB Lden, and two million exposed to at least 40dB Lnight for aircraft noise.

Economic factors

4.33 With resource use and implementation considerations, the GDG acknowledged that the economic evaluation of the health impacts of environmental noise is complicated and extensive for aircraft noise. The systematic review of interventions and the subsequent impact on environmental noise and health shows that there are various measures to reduce noise exposure from aircraft.

4.34 The GDG noted that the resources needed to implement various intervention measures may vary widely, depending on the situation and kind of intervention. Distribution of cost differs compared to other transport sources due to the noise being localised, and the overall population affected is relatively smaller than for the other transport modes.

4.35 Intervention strategies such as discouraging people to move to the area very close to airports, diverting flight paths over less populated areas, installation of soundproof windows are some conventional mitigation strategies that the WHO themselves acknowledge are unlikely to ever achieve the WHO aircraft noise guideline targets. In addition, the guidelines as formulated do not recognise the value of insulation as they are formulated based on outdoor noise exposure levels. Land use planning is more aimed at limiting people moving into noise contours. Removing people from noise contours is much more challenging due to social and land use issues and extremely expensive.

4.36 In relation to active abatement measures, the GDG acknowledged the “balanced approach” elaborated by International Civil Aviation Organization, which states that noise reduction should take place first at the source. As indicated by the Clean Sky Programme, this could, for example, entail shifting towards the introduction of new aircraft. This broad European research programme estimates that, depending on type, the shift to newly produced aircraft could lead to a reduction of approximately 55–79% of the area affected by aircraft noise, and consequently the population exposed.

4.37 It should be noted that this doesn’t acknowledge the long lifetime of an aircraft (25 years on average) and thus the time and cost required for the Clean Sky Programme noise reductions to be realised for all aircraft operations at an airport. Even then, a 55-79% reduction in the area affected will not meet the objectives of the guidelines. Reducing numbers of flights to achieve the WHO guidelines would be extremely expensive and severely impact the aviation network (airport/flight route connectivity). At London Heathrow, populations are currently exposed to noise levels up to 75dB Lden. Reducing population noise exposure to less than 45dB Lden by limiting operations would require the number of operations to be reduced to 1/1000th of the current level, in the absence of any other measures. Even if noise exposure were reduced by other means by 10dB (quieter aircraft or insulation etc), operations would still need to be reduced to 1/100th of current levels to achieve the guideline level.

4.38 The GDG agreed that implementation of the recommendation to minimize the risk of adverse health effects due to aircraft noise for a majority of the population would require a reasonable amount of (monetary) resources. Importantly, it was stated, however, that the feasibility of implementing the measures could be hindered by the fact that costs and benefits are not equally distributed. In most cases, the health benefits citizens gain from interventions that reduce aircraft exposure are borne by private companies and public authorities.

Criticism of the Guidelines

4.39 Following publication of the new Guidelines, Truls Gjestland published a paper criticising the basis for the WHO's new recommendation for limiting aircraft noise annoyance, citing the data set used as 'imperfect and faulty'. He states that the recommendation of a 45 dB Lden limit "is based on the idealistic assumption that nobody should ever be exposed to noise levels which endanger complete individual well-being or quality of life, and, as such, it is useless for general regulatory purposes."

4.40 Gjestland questions why the WHO initially found 15 aircraft noise studies that complied with their inclusion criteria, but then reduced the set to 12 without any real explanation. He points out that two of the studies represented airports with below average annoyance levels. The 12 studies included in the development of the Guidelines were surveys conducted between 2001-2011 and comprise 17,000 respondents as shown in Figure 1 of this document. Gjestland criticises the methods used to derive the final dose-response curve that informs the guideline level of 45 dB Lden, with different regression models having been used in the studies, and the regressions having been based on different noise exposure ranges. He argues that the procedure of applying a regression model to data points derived from other (and different) regression models makes it almost impossible to assess the confidence interval for the final curve.

4.41 The paper also points out that the Guidelines ignore that only about one third of the variance in the response data is explained by the cumulative noise exposure and it effectively prohibits any possibility of studying the influence of non-acoustical factors; an issue that has received an emerging and growing interest.

4.42 Gjestland explains that a visual inspection of the data in Figure 1 shows that for the noise exposure range of most practical interest for regulatory purposes, Lden 50 dB to Lden 60 dB, the prevalence of highly annoyed residents varies between about 5 % and 70 %. Some of the large variation in annoyance even occurs at the same airport, for example two surveys were included at Amsterdam Schiphol; annoyance at 60dB Lden changes from 50% highly annoyed to around 25%, despite the studies being conducted only one year apart. It is difficult to attribute this spread to personal or situational attitudes towards the cumulative noise exposure only. A more plausible explanation would be that there must be other factors that also play an important role. He states that this is not commented on and is overlooked by the researchers responsible for the presentation of evidence for the WHO guidelines.

4.43 The results from six surveys from the HYENA study are included in the WHO full set. The HYENA study was not designed to be an annoyance study, it was a cardiovascular study that looked at hypertension in residents aged 45-70 years. Most surveys have respondents aged 18 years and up. This is for instance, the case for the 20 studies that are included in the Miedema & Vos curve, and which has become the EU standard reference curve for aircraft noise annoyance. It is widely recognised that the annoyance response is age-dependent with a maximum sensitivity around 45 years. Gjestland argues that this intrinsically causes bias and that as 28% of the WHO dataset is comprised of HYENA studies, questions why this was not commented on or addressed.

4.44 There are also concerns regarding the inclusion of Athens and Milan airports, who both have unusually high levels of annoyance. The Athens airport was only opened two years prior to the survey and one of the Milan airports experienced a crash which resulted in many discussions regarding safety. Both were excluded from the HYENA pooled analysis, yet Gjestland points out that Guski et al included both in the WHO full set.

4.45 One of Gjestland's main criticisms is the disproportionate number of High Rate Change (HRC) airports included in the WHO dataset. The WHO have not classified Zurich or Milan in the dataset, but Gjestland argues that they should be classified as HRC due to long-lasting public discussions about flight routes in Zurich. At Milan Malpensa the traffic volume almost tripled in late 1998 when Alitalia moved their major hub to this airport, just over our years prior to the survey. In addition, the crash at Milan Linate occurred just two years prior to the survey. In 2009 the decision to expand the Hanoi Noi Bai Airport had already been made, and the public knew there would be an increase in traffic. The new terminal was opened in 2014 causing a 30 % increase in the traffic volume. Gjestland argues that this should be classified as borderline HRC. Gjestland makes no comment on London Heathrow, but the HYENA 2003 survey was undertaken one year after extensive consultation in 2002 on a new runway at Heathrow, the first consultation to discuss an additional runway at Heathrow for over a decade at the time.

4.46 He explains that if these three airports, Zurich, Milan and Hanoi, are also included in the HRC category, the WHO full dataset comprises 8 out of 12 HRC airports or about to 83 % of the respondents. In the original dataset used by Miedema and Vos for their dose-response curve only 2 out of 20 airports or about 10 % of the respondents were categorized as HRC.

4.47 Gjestland suggests that using the Community Tolerance Level (CTL) developed by Fidell (2011) is a more appropriate method of obtaining dose-response relationships for aircraft noise annoyance. CTL analysis treats the proportion of a community that describes itself as highly annoyed as equally influenced 1) by noise exposure, and 2) by a non-acoustic criterion for self-reporting of annoyance. The growth of annoyance with noise exposure follows the effective loudness function, but the "starting point" on the axis of the response curve is determined by non-acoustic factors. Gjestland argues that the effect of these factors is a real change in noise-induced annoyance, not just an "additional annoyance" caused by other factors.

4.48 The Community Tolerance Level is defined as the value of the noise exposure, DNL, at which 50 percent of the population describes itself as highly annoyed. Each community is treated separately in CTL analysis and characterised by a single value.

4.49 Gjestland conducted a literature search for studies that met Guski's inclusion criteria since 2000. He found 18 studies that he then used for a comparative analysis, with six of them appearing in the WHO full dataset. The number of respondents totals just over 16,000 and half of the airports are categorised as HRC (approximately 60% of respondents). Figure 7 shows the EU curve and the dose-response relationship for the 18 studies post 2000. It also shows the CTL plus one standard deviation.

4.50 The average response lies above the reference curve, indicating a higher prevalence of annoyance. However, the difference between the two curves is less than 1 σ (one standard deviation). Their CTL values differ by only 3 dB, therefore Gjestland states it cannot be concluded that they are significantly different.

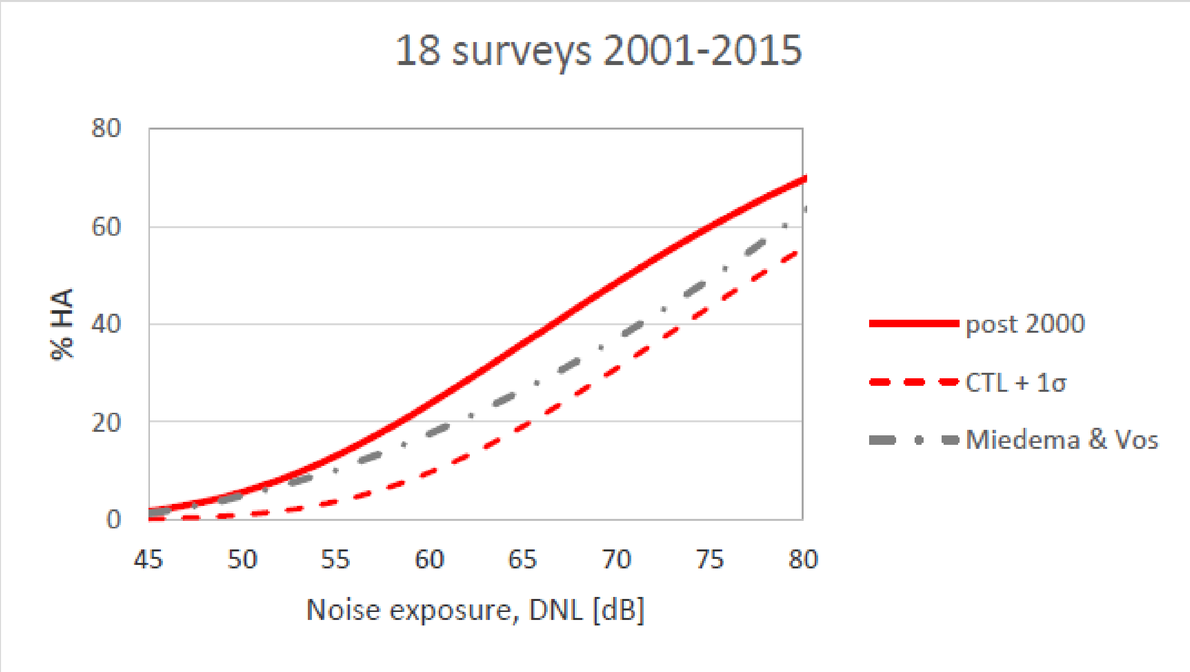

Figure 7: Dose-response curve for 18 post-2000 surveys compared with the EU reference curve (Miedema & Vos) for aircraft noise annoyance.

4.51 The average CTL value for the 12 studies included in the WHO dataset is LCT 66.1 dB with a standard deviation of ± 6 dB. The average unweighted CTL value for the 18 post-2000 surveys is LCT 70.7 ± 7 dB. The results indicate that the respondents to these surveys on average "tolerate" 5 dB higher noise exposure than the WHO selection in order to express the same degree of annoyance.

4.52 Guski (2019) published a response to Gjestland's criticisms and refuted his claims. Guski stated: "We are convinced that the WHO Guideline Development Group did not come to false conclusions and that their recommended guideline value for aircraft noise is not unjustifiably low."

4.53 Guski defends the selection of the airports used in the study and argues that one of the airports Gjestland refers to being omitted from the analysis is a mixed civil and military airport, and was therefore not comparable to the rest of the data set given the differences in perception of military versus civil aviation noise.

4.54 Guski defends the WHO's treatment of non-acoustic factors in the analysis and explains that the review examines between study characteristics, such as study quality rating, survey type, noise level range, response rate, and rate of airport change rather than individual (within-study) variability.

4.55 Regarding the age group of the HYENA study (45 – 75 years), which was included in the WHO meta-analyses, Guski cites findings from other studies that do not show an effect of age on annoyance response as his argument against Gjestland's criticism.

4.56 In answer to the criticism of the inclusion of a majority of high rate of change airports versus low rate of change airports, Guski argues that most airports will have regular construction work occurring, and that there is no such thing as a “representative European airport, or typical airport neighbour”.

4.57 In terms of Gjestland’s criticism regarding the weighting of the studies according to sample size. Guski explains that the studies were weighted according to the square root of the sample size, which reduces the impact of the absolute sample size at larger sample sizes. He argues that this has a less dramatic effect than may be initially thought, and that the influence of the weighting on the WHO aircraft noise dataset is relatively small.

4.58 Finally, Guski refutes Gjestland’s suggestion that the CTL would be a more appropriate approach for obtaining the aircraft noise annoyance dose-response curve. Guski argues that the CTL approach assumes that the form and slope of the exposure–response function is identical for all airports and this is not actually the case when all the response curves are plotted for each of the studies included in the dataset, therefore the CTL approach is no more reliable than the methods used by Guski et al in the setting of the recommendations.

4.59 Gjestland (2019) then published a response to Guski’s paper, concluding: “Guski et al offer no further justification for reliance on non-standardised annoyance questions, limited age-range for the respondents, and potential self-selection biases in the HYENA study. Even if all the surveys analysed by Guski et al had been conducted by irreproachable methods, the fact that a similar analysis of a different (and larger) set of survey data yields a very different result clearly indicates that the findings of Guski et al are not representative of community response to aircraft noise around airports in general.”

Chapter 5
Other findings

5.1 In addition to the findings from the two congresses, Euronoise and Internoise, several other research papers have recently been published on the health effects of aircraft noise.

5.2 One such paper was a German study by Siedler et al, that investigated the effect of aircraft, road, and railway traffic noise on stroke, using secondary data.

5.3 Over a million people aged 40 or above in 2010, living around Frankfurt airport that were insured by one of three large statutory health insurance funds between 2005 and 2010 were included in the study. Address-specific noise exposure was estimated separately for aircraft, railway, and road traffic noise. For aircraft noise, average and maximum sound levels at the centre of the building were calculated according to the guidelines for the calculations of noise abatement zones, using historical radar data from the German flight safety operator.

5.4 The results indicated that for 24-hour continuous aircraft noise exposure, neither increased stroke risk estimates nor a positive linear exposure–risk relationship was observed. However, stroke risk was statistically significantly increased by 7% [95% confidence intervals (95%CI): 2–13%] for people who were exposed to <40 dB of 24h continuous aircraft noise, but ≥6 events of maximum nightly sound pressure levels ≥50 dB (equivalent to at least 25 dB Lnight). For road and railway traffic noise, there was a positive linear exposure–risk relationship. For an increase of 10 dB the stroke risk increased by 1.7% (95%CI: 0.3–3.2%) for road traffic noise and by 1.8% (95%CI: 0.1–3.3%) for railway traffic noise. The maximum risk increase of 7% (95%CI: 0–14%) for road traffic noise and 18% (95%CI: 2–38%) for railway traffic noise was found in the exposure category ≥65 to <70 dB.

5.5 The results indicate that traffic noise exposure may lead to an increased risk of stroke. The authors suggest that maximum aircraft noise levels at night increase the stroke risk even when continuous noise exposure is low. This result supports the hypothesis of disturbed sleep as one pathophysiological mechanism through which traffic noise increases stroke risk. The authors highlight the relevance of maximum noise levels for research and policies on noise protection.

5.6 Carungo et al published a study on the effects of aircraft noise on annoyance, sleep disorders, and blood pressure among adult residents near the Orio al Serio International Airport (BGY), Italy. This airport ranks among the top five Italian airports for number of movements and is now the leading airport for low-cost travel. The methodology was cross-sectional in design, and very similar to that used in the HYENA study.

5.7 Between June and September 2013, 400 participants between the age of 40 -75 years were enrolled in the study (166 in the Reference/Control Zone < 60 dBA, 164 in Zone A 60-65 dBA, and 70 in Zone B 65-70 dBA). Participants also underwent interviews and blood pressure measurements.

5.8 The results indicated that compared to the reference group, annoyance scores were significantly increased for both daytime and night-time in Zones A and Zone B, and there were double the amount of severely annoyed people. In addition, self-reported sleep disorders for the previous month were also significantly increased in Zones A and B. Sleep disorders in general were 19.9% in the Reference Zone, 29.9% in Zone A, and 35.7% in Zone B. The study did not find any relationship between aircraft noise exposure and incidence of hypertension.

5.9 Welch et al (2018) investigated whether those people who are noise sensitive are more adversely affected by airport noise than those who are not noise sensitive. The study was conducted in Wellington city, New Zealand in 2012 and 2015. Residents living within 250 metres of Wellington airport and within the 65 dB Ldn contour, received the postal survey, along with those living in a socio-economically matched Wellington suburb which was not near the airport or close to any other major noise sources. The survey contained 58 items categorised as Health-Related Quality of Life (HRQOL) (26 items), amenity (two items), neighbourhood issues (14 items), environmental annoyances (seven items), demographic information (eight items), and noise sensitivity (one item).

5.10 Noise sensitivity was self-rated on a three-point scale as follows: non-noise sensitive, moderately noise sensitive, or highly noise sensitive. Statistical analysis consisted of analyses of variance using the domains of the WHO Quality of Life (WHOQOL) score with the year, area (airport or the control), and noise sensitivity as covariates.

5.11 The results indicated a two-way (area by noise sensitivity) interaction ($F(2, 353) = 4.06$, $P = 0.018$), suggesting that noise sensitivity had a differential effect on WHOQOL score depending on the area of residence. This result suggested that noise sensitivity was not associated with WHOQOL score in people living in the non-airport area, whereas for those living near the airport, greater noise sensitivity was associated with lower WHOQOL scores (Figure 8). There was no three-way (area by year by noise sensitivity) interaction ($F(2, 342) = 1.16$, $P = 0.314$), suggesting that the effect did not change over time.

5.12 The authors reported that noise-sensitive people who are exposed to noise from aircraft have poorer self-reported health than non-noise-sensitive people with the same exposure, and noise-sensitive people who are not so exposed. They stated that these results replicated some of their previous findings relating to traffic noise exposure from motorways and have also demonstrated that the effect was present in the same geographical areas when measured at time points separated by 3 years. Although in the aircraft noise study socioeconomic status was controlled for in the analysis, the members of the Airport Group tended to be less well educated in both 2012 and 2015 than in the Non-airport Group, and the Airport Group was more likely to have current illness or a medical condition in 2015 compared with 2012.

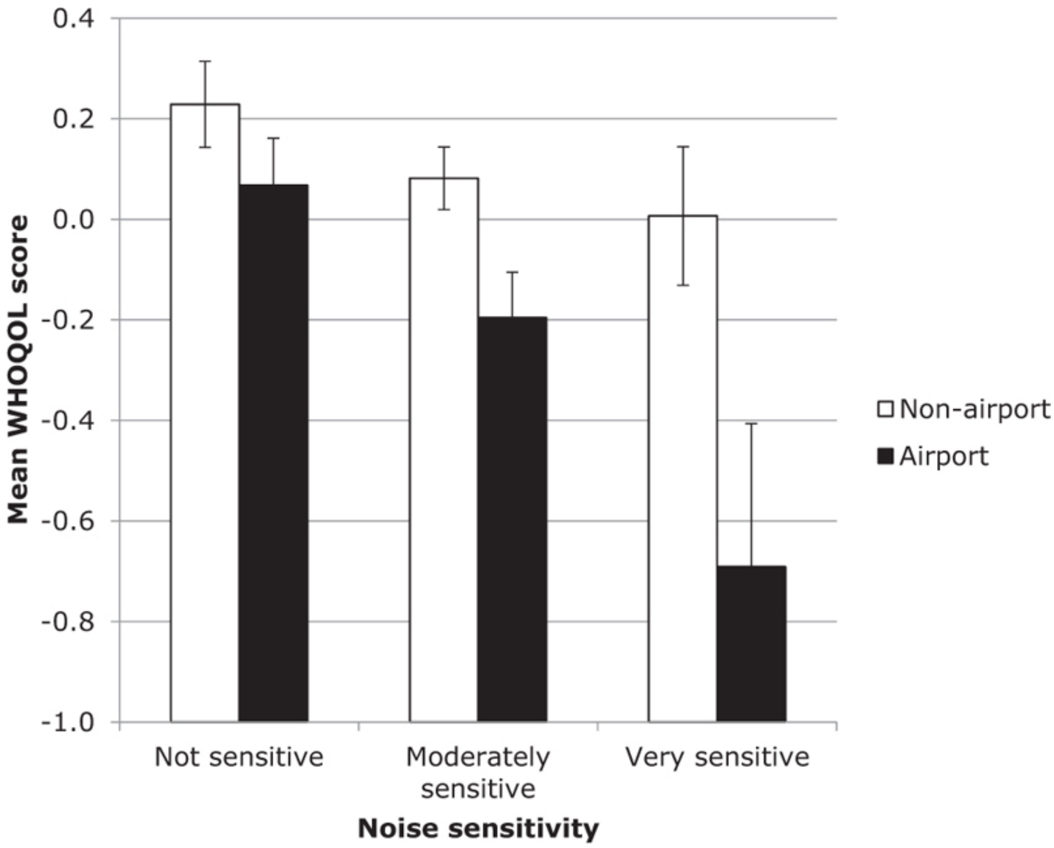

Figure 8: Mean WHOQOL score for each noise sensitivity group and in each area of residence across the years 2012 and 2015. Error bars represent one standard error of the mean.

5.13 Eze et al (2018) published findings on a Swiss study into transportation noise exposure, noise annoyance and respiratory health in adults. The study used over 17,000 observations (from 7,049 participants) from three SAPALDIA (Swiss Cohort Study on Lung and Heart Diseases in Adults) surveys. The authors examined associations between transportation noise exposure and noise annoyance with prevalent respiratory symptoms, and with incident asthma. Annual day-evening-night transportation noise comprising road, railway and aircraft Lden (Transportation Lden) was calculated for the most exposed façade of the participants' residence using Swiss noise models. Transportation noise annoyance was assessed using an 11-point scale, and participants reported respiratory symptoms and doctor-diagnosed asthma at each survey. The authors estimated associations with transportation Lden (as well as source-specific Lden) and noise annoyance, independent of air pollution and other potential confounders.

5.14 The results indicated that transportation noise annoyance, but not Lden, was independently associated with respiratory symptoms and current asthma in all participants, with odds ratios (OR) and 95% confidence intervals (CI) ranging between 1.03 (95%CI: 1.01, 1.06) and 1.07 (95% CI: 1.04, 1.11) per 1-point difference in noise annoyance. Both noise annoyance and Lden showed independent associations with asthma symptoms among asthmatics, especially in those reporting adult-onset asthma [OR Lden: 1.90 (95% CI: 1.25, 2.89) per 10 dB; p-value of interaction (adult onset vs. childhood-onset): 0.03; OR noise annoyance: 1.06 (95%CI: 0.97, 1.16) per 1-point difference; p-value of interaction: 0.06]. No associations were found with incident (doctor-diagnosed) asthma.

5.15 The authors explain that noise annoyance may have a role in influencing the occurrence of respiratory symptoms, and that annoyance and noise level may both exacerbate asthma in adults. It is suggested that there are both psychological and physiological noise reactions that affect the respiratory system, which could be relevant for asthma care. It is concluded that more studies are needed to better understand the effects of objective and perceived noise in asthma cases and overall respiratory health.

5.16 Foraster et al (2018) also used data from the SAPALDIA surveys to examine long-term exposure to transportation noise and its association with adiposity markers and the development of obesity. Over 3700 participants took part in 2001 and 2010/2011, aged 29-72 years at the time. During the first stage, Body Mass Index (BMI) was measured, and at the second phase measurements included BMI, waist circumference, body fat index, and derived overweight, central and general obesity. The authors assigned source-specific 5-year mean noise levels before visits and during follow-up at the most exposed dwelling facade (Lden), using Swiss noise models for 2001 and 2011 and participants' residential history. Models were adjusted for relevant confounders, including traffic-related air pollution.

5.17 The results indicated that exposure to road traffic noise was significantly associated with all adiposity markers and with an increased risk of obesity (RR=1.25, 95% CI: 1.04; 1.51, per 10 dB in 5-year mean). Railway noise was significantly related to an increased risk of being overweight. The authors further identified a stronger association between road traffic noise and BMI among participants with cardiovascular disease and an association between railway noise and BMI among participants reporting bad sleep quality.

5.18 No associations were found between aircraft noise exposure and the development of obesity.

5.19 Wright et al (2018) examined the effects of aircraft noise and self-assessed mental health in residents around Belfast City airport. The study used data from over 198,000 people in the 2011 census, which included the question "Do you have any of the following conditions which have lasted, or are expected to last, at least 12 months?" followed by a list of 11 conditions. An affirmative response marked for "an emotional, psychological or mental health condition (such as depression or schizophrenia)" was the measure of self-assessed chronic poor mental health. Chronic physical conditions were also measured as markers of co-morbidity.

5.20 The results indicated that the incidence of self-assessed mental ill health was greater in high noise areas of ≥57 dB LAeq,16h, in comparison to lower noise areas of < 54 dB LAeq,16h (12.4% vs. 9.7%, respectively). However, no association was found between aircraft noise and risk of mental ill health following adjustment for socioeconomic status.

5.21 The authors conclude that findings from this study indicate that noise from this airport (a smaller, regional airport in comparison to other studies, with fewer flights and no night flights) does not significantly affect the mental health of the surrounding population.

5.22 Looking ahead, two new UK studies are planned to provide further evidence regarding the health impacts of aircraft noise. Researchers from the University of Leicester and Imperial College London (funded by the National Institute for Health Research) are researching short-term effects of aircraft noise from Heathrow airport with regard to hospital admissions and deaths from cardiovascular disease.

5.23 Researchers from the University of Leicester, Imperial College London, King's College, and University College London (funded by the Medical Research Council) are undertaking the first comprehensive study of long-term cardiovascular impacts of aircraft noise near major airports in the UK. The aim is to examine whether there is an association between aircraft noise and mortality and hospital emissions, along with risk factors such as high blood pressure and heart rate variability.

5.24 Both UK studies will be completed by 2020 and it is expected that evidence from these studies will be used to inform and support policy on aircraft noise in the UK and further afield.

Chapter 6
Summary

6.1 This report has provided a summary of some of the main findings in 2018 with regards to aircraft noise and health effects. It has included the recommendations from the WHO Guidelines for Europe, published in October 2018 and discussed some of the criticisms surrounding the derivation of those recommendations. Findings from Internoise and Euronoise have also been highlighted. It is expected that summary reports such as these will be published on a yearly basis and continue to include all health outcomes that are investigated in relation to aircraft noise exposure.