Aircraft Noise and Health Effects: a six-month update

CAP 2519

Contents

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 September 2022 - March 2023. The report will provide an overview of the most relevant findings that were published during this period.

1.2   The aim of the report is to provide a succinct overview of new work relating to aviation noise and health, and such updates are 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.

1.3   The findings in the following chapters are grouped by subject area.

CHAPTER 2
Aircraft Noise and Cardiovascular Effects

2.1   There were several papers on the effects of aircraft noise and cardiovascular effects published during this six-month period. This chapter summarises these findings.

2.2   **Bączalska et al** published a review on the cardiovascular consequences of aircraft noise, in the context of the authors' previous findings in relation to early, potentially reversible changes that preceded longer term cardiovascular disease. The review included 13 studies from Germany, Switzerland and Poland and discusses the early risks of aircraft noise exposure, such as psychophysiological stress causing non-auditory or indirect noise effects such as activation of the autonomic nervous system which can include increases in heart rate and blood pressure, which can then lead to cardiovascular diseases. Increases in arterial stiffness and left ventricle diastolic function have also been associated with long-term aircraft noise exposure. The authors describe all these effects as being early, sub-clinical and potentially reversible changes as opposed to late noise effects in the cardiovascular system such as myocardial infarction (heart attack), stroke, and heart failure.

2.3   In addition to the review discussing previous findings with relation to aircraft noise and cardiovascular effects, the authors also discuss the effects of noise reduction, and the potentially reversible nature of some of these early effects. A 2022 German study by Wojciechowska et al is described, which followed on from a Rojek study in 2015. During the follow-up after of 5.5 years, there was a sudden decline in air traffic for about 4 months took place due to the COVID-19 lockdown. As a result, the average aircraft noise level decreased from 61 to 47 dB L_{Aeq} during the day and 55.4 to 43.4 dB L_{Aeq} during the night period in the region previously categorised as exposed to aircraft noise in 2015 (>60 dB L_{den}). Therefore, both investigated study groups were exposed to similar levels of aircraft noise.

2.4   At the follow-up, the group initially exposed to aircraft noise (>60 dB L_{den}) exhibited an increase in hypertension, which suggested that long-term exposure resulted in long-term increased hypertension risk. In both highly exposed and low exposed (>55 dB L_{den}) groups, a decrease in pulse wave velocity[1] (PWV) was found, with a more marked decrease in the highly exposed group, as a result of

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[1]   Pulse Wave Velocity (PWV) is the propagation speed of the wave-induced along the aorta and arterial tree, each time the heart beats. PWV increases with increased arterial stiffness, thus establishing it as a reliable prognostic marker for cardiovascular morbidity and mortality.

the sharp decrease in noise. The authors found a similar finding for annoyance, with a more marked decrease in the group originally exposed to higher aircraft noise levels. Lower blood pressure was observed in both groups, with some measures decreasing to a larger extent in the higher exposed group.

2.5   The authors suggest that the findings in this study revealed that even the short-time reduction of aircraft noise can reverse the long-term effect on blood pressure and arterial stiffness. It is concluded that the finding that such outcomes may be reversible in this way highlights the need for aircraft noise level restrictions, and the case for adherence to World Health Organisation (WHO) recommendations is presented.

2.6   **Nguyen et al** published a paper on the effects of long-term aircraft noise and hypertension risk in post-menopausal women. The rationale for this study is that hypertension is a known risk for cardiovascular disease and is highly prevalent in populations such as older women. The hypothesis for the association between aircraft noise and hypertension is that the aircraft noise acts as a stressor, and results in the release of stress hormones within the body, or via sleep disturbance pathways, resulting in vascular dysfunction.

2.7   Previous studies have suggested that there are socio-demographic differences in noise exposure around airports in the US, and also in hypertension prevalence. This study used modelled aircraft noise data from 90 airports in the US and examined the longitudinal association between exposure to aircraft noise and incident hypertension in the Women's Health Initiative (WHI) Clinical Trials. The WHI is a large, national U.S. prospective cohort that enrolled over 68,000 post-menopausal women ages 50–79 years into clinical trials at 40 clinical centres from 1993 to 1998.

2.8   Participants were randomised into one or more overlapping Clinical Trials:

1) menopausal hormone therapy,

2) dietary modification, and/or

3) calcium/vitamin D supplementation.

2.9   Participants were originally followed until the end of the main study in 2005, while a subset (82%) participated in the five-year Extension I study which continued follow-up data collection until 2010. The authors excluded participants with baseline hypertension (n = 30,813), no follow-up data (n = 121), and missing noise exposure during follow-up (n = 746), resulting in 36,542 participants at risk of hypertension.

2.10   Noise contours were provided by Volpe for the 90 airports for years 1995, 2000, 2005, and 2010. The metrics DNL and L_{night} were modelled in one dB(A) increments ranging from 45 (considered background noise) to 75 dB(A).

2.11   There were 18,783 participants with non-missing DNL exposure and 14,443 with non-missing L_{night} exposure at risk of hypertension. The results indicated that those participants who were exposed to DNL and $L_{night} \geq 45$ dB(A) at baseline were more likely than those who were unexposed to aircraft noise to live in more densely populated areas, live closer to major roadways, live in areas with higher levels of air pollution ($PM_{2.5}$ and NO_2), be a race other than White, be of Hispanic or Latino ethnicity, have lower family household income, and lack health insurance. There was a moderate positive correlation (r = 0.35) between DNL and L_{night} estimates.

2.12   Of those exposed to DNL ≥45 dB(A), 42.3% (n = 3392) developed hypertension, and of those exposed to L_{night} ≥45 dB(A), 35.7% (n = 367) developed hypertension (DNL <45 dB[A] cases 46.9%; L_{night} <45 dB[A] cases 43.9%). The authors did not find a positive relationship between increasing categories of noise exposure and the risk of hypertension in the studied population. The associations between DNL estimates of aircraft noise and incident hypertension were more pronounced among participants living in those areas with a lower population density, or lower NO_2 levels. Similar results were found when instead considering the associations between L_{night} estimates of aircraft noise and incident hypertension, there were similar patterns with respect to population density and NO_2, and higher estimates for participants with a Body Mass Index of ≥20 kg/m2, or women aged 61 years or less.

2.13   The authors explain that the finding of no association with aircraft noise and hypertension remained stable across several sensitivity analyses, including different estimates of aircraft noise, and adjustment for various potential confounding factors. The outcomes of other long-term aircraft noise and hypertension studies are discussed, and findings are not consistent throughout. It is considered that men report higher levels of aircraft noise than women, and some studies indicate a higher level of hypertension in men than women. Noise annoyance has also been shown to have an inverted U-shaped pattern with age, where the percentage of highly annoyed people peaks at 45 years of age and decreases thereafter.

2.14   The limitations of the study are considered, such as relatively few participants exposed to higher noise levels for L_{night}. Address-based estimates of ambient noise may not be representative of true personal exposure that is likely influenced by factors such as time-activity/ mobility patterns, quality/construction of housing, room orientation, or window-opening behaviours may also bias findings towards the null hypothesis of no association.

2.15   **Sivakumaran et al** conducted a systematic review on the impact of noise exposure and the risk of developing stress-related health effects related to the cardiovascular system. The review timescale was from January 1st, 1980, to December 29th, 2021. The objective of this systematic review was to update the

available evidence, to evaluate the strength of evidence for an association between noise exposure and changes in the biological markers known to contribute to the development of stress-related cardiovascular responses.

2.16   The review included studies published in English and conducted in humans that provided at least one comparison of noise levels reporting on stress reactions. The authors included studies reporting on the following outcomes: blood pressure, hypertension, heart rate, cardiac arrhythmia, vascular resistance, and cardiac output. The GRADE (Grading of Recommendations Assessment, Development, and Evaluation approach) was used to assess the evidence for each outcome.

2.17   For the blood pressure outcome, 78 studies were found, with four studies on aircraft noise were included in the review, and the data presented. One cohort study reported that increased air traffic noise may have little to no effect on blood pressure; however, the certainty of the evidence was very low. Among cross-sectional studies (n = 3), an increase in air traffic noise may have little to no effect on blood pressure (MD: 0.63, 95% CI: –1.87, 3.13; MD: 0.58, 95% CI: –0.90, 2.05; for systolic and diastolic blood pressure, respectively; with very low Certainty of Evidence).

2.18   65 studies were found on noise and hypertension risk, with five studies included on aircraft noise. Among cross-sectional studies (n = 2), no strong evidence that air traffic noise was associated with hypertension was found. Among cohort and case-control studies (n = 3), it was suggested that every 10 dBA increase in aircraft noise may increase the risk of hypertension by 10% (RR: 1.10, 95% CI: 0.95, 1.27; with very low Certainty of Evidence).

2.19   43 studies were included on heart rate and noise, but there was very low Certainty of Evidence for the effects of noise on heart rate. It is explained that findings indicated that exposure to higher levels of road traffic, railway, aircraft traffic, ambient, or laboratory-simulated noise may have little to no effect on heart rate, but the evidence was very uncertain.

2.20   Exposure to the road, railway, or aircraft noise was found to have little to no effect on the risk of atrial fibrillation; however, the evidence was very uncertain.

2.21   The authors discuss gaps in research and questions to be answered. They explain that concerns with included studies were largely due to the lack of adjustments for critical confounders, as well as differences in the measurement of the noise exposure and outcome. Measurement of noise exposure and sources of exposure varied across studies and many outcomes such as blood pressure require multiple measurements at different time points to confirm the outcome measure. It is concluded that exposure to higher levels of noise may increase the risk of some short and long-term cardiovascular effects, but the certainty of the evidence was very low.

2.22   **Kim et al** (2022) published their study findings on long-term aircraft noise exposure and risk of hypertension in the Nurses' Health Studies. The Nurses' Health Studies (NHS) started in 1976 and is comprised of over 121,000 female nurses who were born between 1921 and 1946, living in one of 11 states in the US at the time they were invited to participate. NHS II enrolled 116,00 female nurses who were born between 1946 and 1964, living in 14 states at baseline in 1989. The aim of this study was to examine the association between aircraft noise and incident hypertension in two cohorts of female nurses, using aircraft noise exposure estimates with high spatial resolution over a 20-year period.

2.23   Questionnaires were sent by post to the participants every two years, and included questions on demographic and physical characteristics, health status, lifestyle, and family disease history. Participants of each cohort self-reported hypertension diagnoses biennially. Hypertension incidence was defined as a new report of doctor-diagnosed high blood pressure since the previous questionnaire. Modelled noise contours for 1995, 2000, 2005, 2010, and 2015 for 90 U.S. airports were obtained from Volpe.

2.24   The final dataset included a total of just over 162,000 participants, with 63,000 and 98,900 participants from NHS and NHS II, respectively. The analyses were limited to years 1994–2014 for NHS and 1995–2013 for NHS II, due to the availability of the noise data. The authors used a 45 dB(A) DNL cut-off point in order to assess the impact of modelled aircraft noise exposures above background, and a 55 dB(A) DNL cut-off point to further examine the exposure-response relationship and controlled for confounding variables.

2.25   The results when aircraft noise was categorised at 45 dB(A) DNL, showed hazard ratios (HR) for hypertension incidence of 1.04 (95% CI: 1.00, 1.07) and 1.03 (95% CI: 0.99, 1.07), respectively for the two cohorts. When analysed at 55 dB(A) DNL as the cut-off, HRs were 1.10 (95% CI: 1.01, 1.19) and 1.07 (95% CI: 0.98, 1.15) for the two cohorts, respectively. After conducting fully adjusted sensitivity analyses limited to years in which particulate matter (PM) was obtained, the authors observed similar findings.

2.26   The authors concluded that the results indicated a marginally suggestive relationship between aircraft noise exposure and hypertension in the NHS and NHS II cohorts, with and without adjustment for other risk factors. It is explained that the number of participants living close to airports was relatively small, and the populations were not exposed to high levels of aircraft noise due to the study not being designed for this purpose. Less than 10% of the NHS and NHS II participants at baseline were exposed to aircraft noise as a result of living near one of the 90 airports included in the noise exposure assessment (with DNL ≥45 dB(A)). About 1% of the participants were exposed to aircraft at DNL ≥55 dB(A). The authors were also unable to control for other sources of noise such as road traffic noise, which may also contribute to hypertension.

2.27   **Bozigar et al** published findings on associations between aircraft noise exposure and adiposity[2] in the US based prospective Nurses' Health Studies. The questionnaires that were sent out every two years included questions on BMI and associated confounders. BMI was modelled against aircraft noise categories 45, 55 and 65 dBA DNL levels. All categories of aircraft noise were associated with increased odds of reporting BMIs of 25-29 or above, with the strongest association at 55 dBA DNL. The authors conclude that in the NHS cohorts, higher aircraft noise exposure groups were associated with higher BMI categories. The relationship was independent of multiple factors influencing BMI over time, suggesting the importance of an adiposity pathway for noise induced health effects.

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[2]   Adiposity is defined by the WHO as a BMI of over 30 kg/m^2

CHAPTER 3
Aircraft Noise and Children

3.1   **Sivakumaran et al** conducted a systematic review on the impact of noise exposure on the risk of developing stress-related obstetric health effects. The rationale for this review was that although noise exposure can produce stress reactions, and therefore potentially affect pre-natal levels of stress in pregnancy and the possibility of adverse obstetric outcomes, the relationship between noise exposure and adverse obstetric outcomes have not been widely studied.

3.2   The review was from 1980 to 2021 and the objective of the systematic review was to examine the association between noise exposure and the risk of stress-related obstetric effects, specifically pre-eclampsia (high blood pressure), gestational diabetes, and gestational hypertension.

3.3   The search identified 11,000 records, of which six primary studies reporting on obstetric outcomes were included. The only study on aircraft noise to be included was a combined exposure study by Thacher examining road, railway and aircraft noise and gestational diabetes. Based on the quality of evidence, the association between exposure to road traffic noise and gestational diabetes was deemed to be very uncertain due to the authors' concerns with the risk of bias. It was concluded that due to the limited evidence in this area, additional research is needed to understand the effect of noise from various sources, such as railway and aircraft traffic, on adverse obstetric outcomes.

3.4   **Dohmen et al** published a review on the effects of noise on cognitive performance and helplessness in childhood. The paper consists of a systematic literature review, performed to assess to what extent the current evidence addresses the effects of the sound environment on cognition and learned helplessness, as measured by motivation in children and young adults up to the age of 21.

3.5   The authors provide a background to learned helplessness, and explain that is is more than stress, it is a broad psychological concept and is focussed on the perception of control. Learned helplessness is defined as: the state that occurs when "an organism learns that its behaviour and outcomes are independent, and that this learning produces the motivational, cognitive, and emotional effects of uncontrollability." Learned helplessness occurs when an individual continuously faces a negative, uncontrollable situation and stops trying to change their circumstances, even when they have the ability to do so. It can show up as three possible deficits: motivation, emotion, and cognition.

3.6   The motivational aspect can be described as knowing that one's behaviour will not affect the outcome, one does not initiate the behaviour. In relation to task performance, this is most commonly measured as task persistence. Emotional effects of learned helplessness include depression or a low emotional state. Cognitive effects of learned helplessness include the fact that it is difficult to learn that a failed coping mechanism or failed behaviour in one situation can be helpful in another. When applied to the effects of noise, important factors include perceived control over the noise source, and ability to complete tasks under noisy conditions.

3.7   The paper summarises previous research investigating the effects of noise on children's cognitive performance. It is known that chronically noise exposed children are also more vulnerable to learned helplessness, possibly as a result of experiencing less perceived control over their environment. Chronically exposed children also perform worse on cognitive tasks. The authors explain that understanding how cognitive function and learned helplessness interact can give more insight into the the effects of environmental noise on learning and child development.

3.8   The systematic review resulted in eight papers being included, that included learned helplessness and cognition. The eight papers referred to four different studies. The four studies were the Los Angeles Noise Project, the Munich Airport Study, the Heathrow Study and the ALPINE study. The first three studies all examined the effects of chronic aircraft noise on cognition and learned helplessness. The ALPINE study looked at road and railway noise. The LA project and the Munich study were longitudinal design, the Heathrow and ALPINE study were cross-sectional. The participants of all the studies were primary schoolchildren in the ages 8–13. The main direction of the effects of noise on cognitive performance and helplessness (measured in motivation) are shown in Table 1.

Table 1: Task performance results of the exposed group compared to the non-exposed control group. Arrows indicating lower or higher performance, size indicating full (large arrow) or partial (small arrow) relationship, colours indicating if the differences are positive (green) or negative (red) for the exposed group. Yellow stripe indicates no differences between groups.

3.9   The authors stated that comparisons between the studies was difficult due to the differences in noise measurements, cognitive tests and methodological approaches to learned helplessness. The longitudinal studies (LA and Munich studies) were found to have higher degrees of bias than the cross-sectional studies (Heathrow and ALPINE) due to the noise indicators used, and all studies scored high on bias because participants were intentionally selected to represent either an exposed or unexposed noise group rather than being randomly selected.

3.10   The authors concluded that there are indications that environmental noise is associated with learned helplessness effects, with regard to motivation. Due to the small age range studied, there remains questions on different developmental stages in children with respect to learned helplessness. In the longitudinal

studies the effect on motivation remained over time, even after the removal of the noise source. The authors suggest that further research into differences in age, gender, and social background could also be beneficial to assess the vulnerability to learned helplessness in conjunction with stress factors such as environmental noise.

3.11   **Terzakis et al** published a systematic review on noise indicators relating to non-auditory health effects in children (< 18 years) conducted between 2000 and 2020. The purpose was to investigate which objective noise indicators related to various noise sources (i.e., aircraft, road-traffic, and ambient noise) are the best predictors of non-auditory health-effects in children.

3.12   The relationship between non-auditory health effects and noise exposure in children has been previously investigated, including psychophysiological, cognitive, mental, sleep, and physical development aspects. The authors explain that children are more sensitive to noise, indicating that their coping strategies may have not been entirely developed and therefore making them more vulnerable to the effects of noise. The importance of identification of the noise indicators associated with non-auditory health effects in children is stressed in this review, especially with respect to the noise source, noise location, and the children's age.

3.13   The types of noise included were ambient, aircraft and road traffic noise. Children's homes and schools were considered the main locations for noise. 36 papers were included in the review. Cardiovascular outcomes related to systolic and diastolic blood pressure were significantly associated with both aircraft and road-traffic noise. The L_{Aeq} indicator presented significant associations with both types of blood pressure. Cortisol, gluccocorticoids[3], and their metabolites were the main neuroendocrine outcomes explored with respect to road-traffic and aircraft noise exposure. In terms of memory tasks, long-term memory was found to be impaired by noise exposure, (L_{Aeq}), compared to short-term memory. Working memory tasks, associated with short-term memory, did not reveal any significant association with respect to aircraft and road-traffic noise exposure. However, recognition memory tasks, associated to long-term memory, were significantly impacted by both types of noise exposure.

3.14   Noise events, L_{Amax} and the LA_{10} indicator (the noise level exceeded for 10% of the measurement period), as well as background level, revealed significant associations to cognitive performance tasks (i.e., language, mathematics, and science), considering exposure in educational buildings. Language and

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3   Glucocorticoids are cholesterol-derived steroid hormones synthesised and secreted by the adrenal gland. They are anti-inflammatory in all tissues, and control metabolism in muscle, fat, liver and bone. Glucocorticoids also affect vascular tone, and in the brain influence mood, behaviour and sleep–wakefulness cycles.

mathematics tasks were found to be significantly affected by aircraft noise (L_{Aeq}) when measured in educational buildings. Annoyance and wellbeing had strong associations with aircraft and road traffic noise. The impact of aircraft noise exposure on motivation was only addressed by one study. In this study a non-significant relationship was found between motivation and L_{Aeq}. Mental disorders associated with anxiety and depression did not present a significant association with aircraft noise exposure.

3.15   The authors present a conceptual framework for the relationship between noise exposure and non-auditory health effects in children (Figure 1).
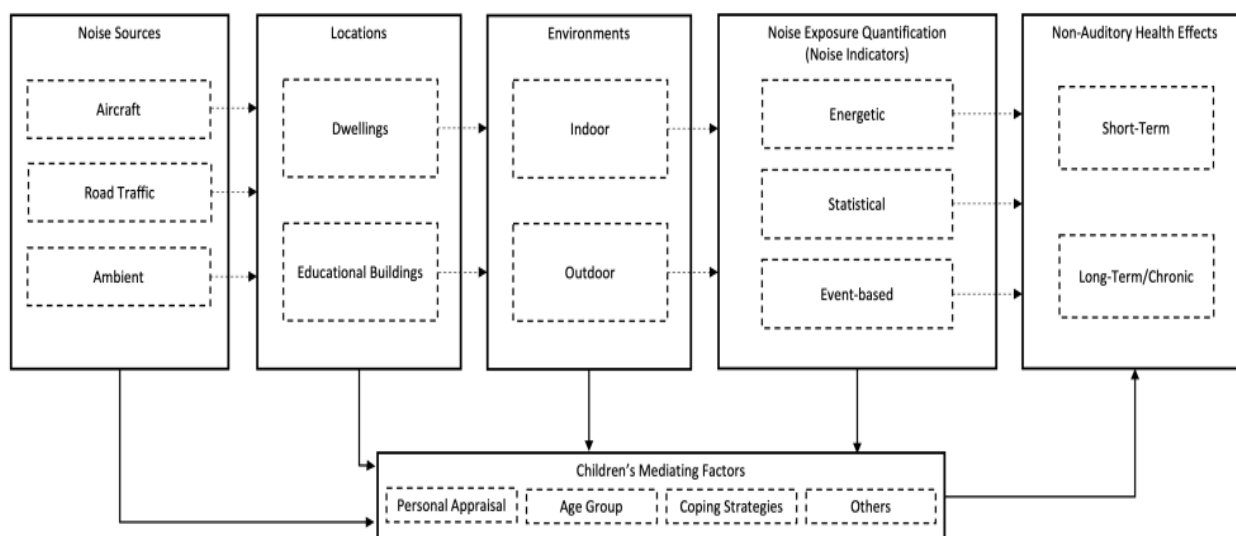
Figure 1: Conceptual framework of the relationship between noise exposure and non-auditory health effects in children.

3.16   The authors explain that the noise exposure is associated with the type of the noise source, the locations, and its environments' characteristics. The noise indicators (energetic, statistical, or event-based) are the quantities for correlating noise exposure and/or its characteristics with non-auditory health effects. Finally, mediating factors can influence the strength of the associations between noise exposure quantification and possible health effects in children.

CHAPTER 4
Other findings

4.1 Welch et al published a paper discussing the issue of noise sensitivity and questions the meaning of this term. The authors present a discussion of the background to how sensitivity to noise has been measured and how the aim of this study was to compare three methods of assessing noise sensitivity with respect to aircraft noise.

4.2 The first of the three measures is the Loudness Discomfort Level (LDL), which is a direct, psychoacoustical approach that uses laboratory settings. LDLs are the levels of pure tones, across frequencies, at which a person reports discomfort to sounds. They are used in clinical settings and for comparisons to other measures of noise sensitivity. The second measure to be included in this study is the NoiSeQ, which is a German-developed multi-dimensional approach has 35 items, rated with a 5-point scale ranging from "strongly agree" to "strongly disagree." The scale allows for either an overall measure of noise sensitivity or separate noise sensitivity areas can be obtained from subscales for work, leisure, habitation, communication, and sleep. The authors explain that the NoiSeQ is effective for low to high noise sensitivity values, and is not influenced by sex or age, has good internal reliability, and has been used widely in field studies. The third measure is one the researchers have used in previous research and is a three-point noise sensitivity scale (3-NS), (not noise sensitive, about average, highly noise sensitive). The authors proposed that if all three measures were actually measuring the same outcome, then the scores would be expected to correlate. Conversely, if noise sensitivity relies on a series of interactions, the correlations between the measures would be expected to be weaker.

4.3 The second phase of the research investigated how well the three different measures of noise sensitivity predicted noise annoyance and/or the perceived loudness of the sounds of aircraft overflights. As noise sensitivity is believed to moderate the response to noise, the authors hypothesised that the measures of noise sensitivity would predict annoyance and loudness outcomes.

4.4 There were 30 adult participants in the study, which was conducted in a sound-minimising chamber. The three measures of noise sensitivity were performed; the NoiSeQ questionnaire was completed by the participants, the 3-NS was also answered individually and the LDLs were obtained across the octave frequencies of 250 to 8000 Hz were obtained for both ears of participants. The methodology for this was described as: 'The initial stimulus intensity was 50 dB HL, and frequencies were tested in the order: 1000, 2000, 4000, 8000, 500, 250 Hz. Pure

tones were presented for approximately 2 seconds, with a 1-second interval between each presentation. A 2-dB step size was employed, until the participant indicated discomfort by pushing the response button.'

4.5   To measure the interaction between noise exposure, sensitivity and annoyance, participants were played a 15-second overflight (80 dB L_{Aeq}). Immediately after each aircraft overflight noise condition, participants provided responses on the perceived loudness and annoyance scales. Each participant experienced three repeats requiring separate loudness and annoyance ratings, and their final score was the mean of the three responses. The loudness scale was a 9-point scale, and the annoyance scale was the ICBEN 11-point scale.

4.6   The findings indicated that the three sensitivity measures were only weakly correlated. The NoiSeQ and the overall LDL score correlated r = −0.260, P = 0.164, and the LDL was not associated with the other measures. Interestingly, an outlier in the data of an LDL of < 50 was removed from the data, yet this increased the strength of the association, therefore was removed from the analysis. Scores on annoyance and loudness were highly correlated (r = 0.834, P < 0.001).

4.7   LDL was found to predict the annoyance and loudness ratings of aircraft noise; the other measures of sensitivity did not significantly achieve this. However, the authors explain that the direction of effects from all of the measures was that more noise-sensitive people tended to rate the sound as louder and more annoying. When the model included all three measures of noise sensitivity, the overall prediction ability did not improve. The authors explain this finding as the variance in loudness and annoyance explained by the three measures was shared.

4.8   The differences between the three measures are discussed as a possible reason for the lack of associations between them. For example, the NoiSeQ is far more detailed than the simplistic 3-NS measure, and asks about sensitivity in different settings, and the LDL examines intolerance to noise levels. The authors suggest that the concept of noise sensitivity being a single trait is incorrect, and that in fact sensitivity is comprised of different aspects. They explain that noise sensitivity can mean different things and can be contextual, and some examples include: loudness intolerance, ease of distraction from tasks by noise, likelihood of sleep disturbance, being upset by loud noises, being irritated by quiet noises, having difficulty hearing in background noise, having a negative attitude toward sources of noise, inability to identify other sounds clearly due to masking effects. In self-reporting of sensitivity to noise, participants may be reflecting on any of these outcomes. The authors present a process by which noise sensitivity occurs, which is shown in Figure 2.
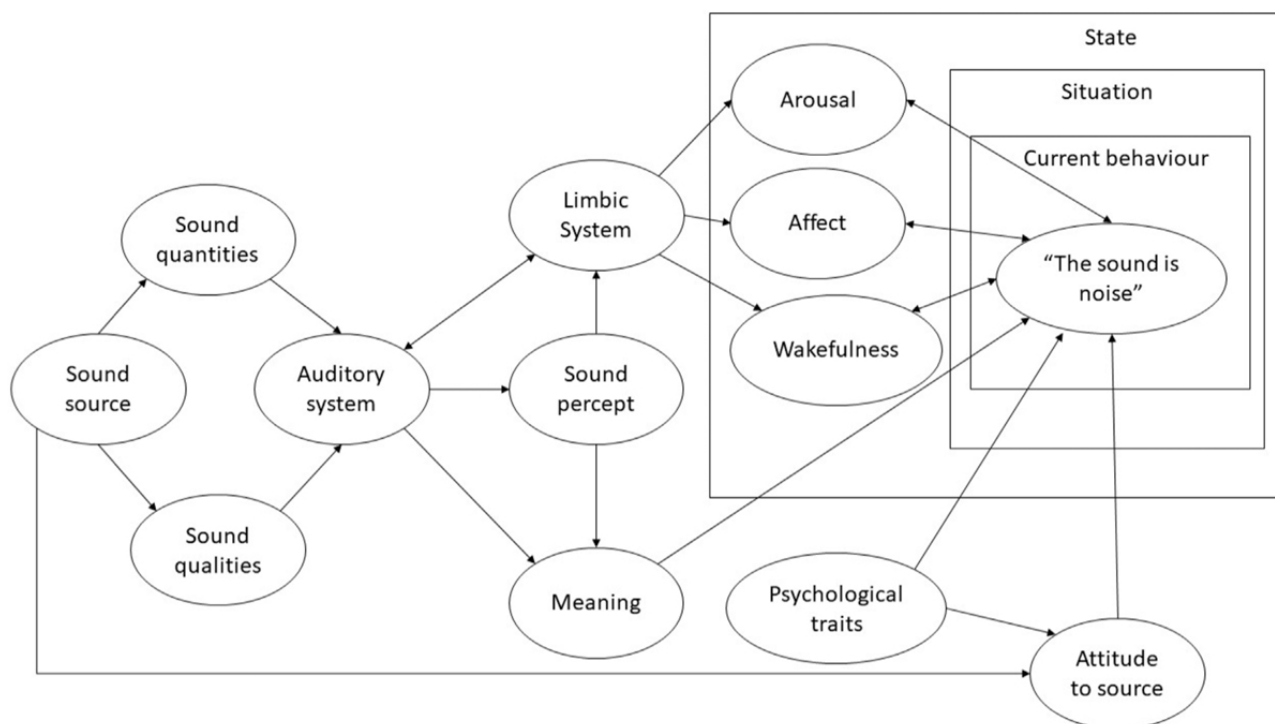
Figure 2: Process diagram of a system model of noise sensitivity.

4.9   The authors explain the processes shown in the figure as a sound has characteristics that may be detected by the auditory system. If detected, the sound is interpreted for meaning, while in parallel, the information passes into the limbic system in the brain where it can contribute to physiological arousal, mood, and wakefulness. Depending on a person's state, situation, and what they are doing, combined with their psychological traits and their attitude to the source of the sound, they may interpret the sound as "noise." They propose that noise sensitivity is not merely a psychological trait, but rather the result of a series of variables and processes that combine to produce it.

4.10   **Schubert et al** published findings on high noise levels from transportation noise and sleep disturbance from the Leipzig Research Centre for Civilization Diseases (LIFE) study. The aim was to compare the exposure-response findings from this study, with those found in the WHO environmental noise guidelines for the European region. The systematic review by Basner and Maguire on sleep disturbance that fed into these guidelines, resulted in recommended night-time road traffic levels below 45 dB L_{night}, below 44 dB L_{night} for rail traffic and below 40 dB L_{night} for aircraft noise.

4.11   The aim of the LIFE study was to assess the relationship between Highly Sleep Disturbed (HSD) people and transportation noise for Leipzig, a major city in Germany, and to establish exposure-response functions.

4.12   The study population includes 10,000 randomly selected residents (mainly ≥ 40–79 years old, and an additional subset of 400 individuals aged 18–39 years) living in Leipzig. The data for this paper was collected from questionnaire data from the second wave, which was conducted from June 2018 to December 2021 (n = 5670). For the second wave, an additional questionnaire on sleep disturbances from road, rail and aircraft traffic noise was included. The questionnaire was developed as part of the NORAH study. Self-reported sleep disturbances from individual traffic noise sources when falling asleep, during sleep and while waking-up during the last 12 months were determined using the ISO 5-point scale. Residential exposure to road, rail and air traffic was determined for the most exposed façade at 4 m height for the year 2012.

4.13   The results indicated that approximately 2.7% of participants were HSD from road traffic noise, 1.2% from rail traffic noise and 2.0% from aircraft noise. Slightly more women tended to be HSD from road and aircraft noise than men (road: 3.1% versus 2.2%; air: 2.3% versus 1.7%). Participants aged between 50–59 years had the highest proportion of aircraft noise-related HSD (about 3.0%).

4.14   Figure 3 displays a comparison between the exposure-response curves derived from data in the LIFE study, and that from the WHO review on sleep disturbance, for road, railway and aircraft noise.
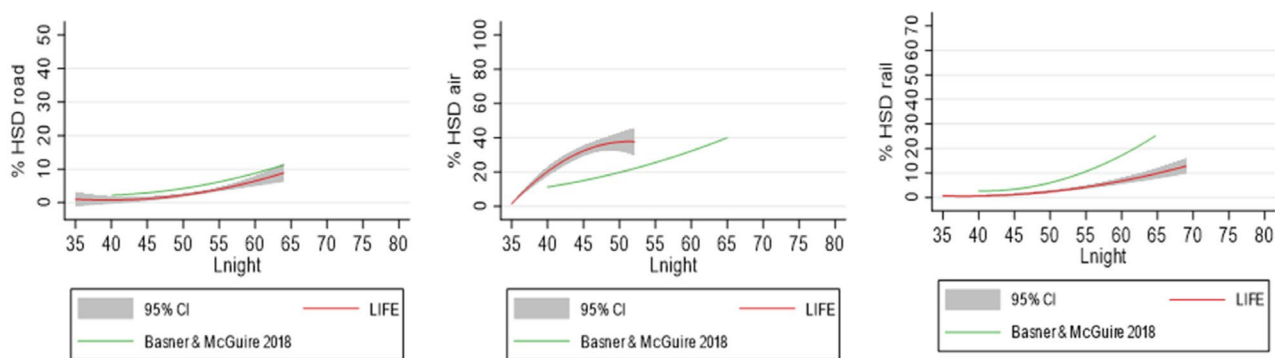
Figure 3: Comparison of HSD risk curves for road traffic, rail traffic and aircraft noise between the LIFE study and the WHO (Basner and McGuire 2018).

4.15   The authors explain that for aircraft noise, the proportion of HSD was considerably higher in the LIFE study than for the WHO review. The %HSD increased from 1% at 35 dB to 32% at 45 dB in the LIFE study. For road and rail noise, the calculated 3% HSD threshold (set in the WHO EU guidelines) was reached at 45 dB L_{night} for the WHO and at 51 dB L_{night} for the LIFE study. The highest risk for traffic noise-related HSD was found for aircraft noise: the risk increase was OR = 19.66, 95% CI 11.47–33.71 per 10 dB increase in L_{night}. For

road and rail traffic, similar risk estimates were observed (road: OR = 2.86, 95% CI 1.92–4.28; rail: OR = 2.67, 95% CI 2.03–3.50 per 10 dB L_{night} increase). The proportion of individuals with HSD for a given noise level was lower for rail traffic but higher for aircraft noise in the LIFE study than in the WHO curves. Road traffic exposure-response curves were not directly comparable, due to a secondary road network being included in the LIFE study.

4.16   The authors explain that these findings are in support of previous findings that also indicate a higher level of sleep disturbance due to aircraft noise compared to road and rail noise. For aircraft noise, the exposure-response function was considerably higher compared with WHO (LIFE: 45 dB, 32% and 55 dB, 36%; WHO: 45 dB, 15% and 55 dB, 26%). These results are comparable to the results of other studies in Innsbruck and the Swiss SiRENE study for 55 dB L_{night}. In both studies, about 40% of participants were HSD at this noise level. At 45 dB L_{night}, the proportion of HSD was about 20%, and therefore lower compared to the LIFE study.

4.17   The possible reasons for the discrepancy between the LIFE findings and the WHO review are discussed, such as an increased in air traffic movements between 2010 and 2019, and the number of night flights for freight using large military aircraft being half of all flights per day. Due to this increase in movements, Leipzig could be considered a 'high rate of change' airport, which have been observed to elicit higher annoyance responses than low rate of change airports.

4.18   The authors conclude that due to the increased levels of sleep disturbance at lower levels in this study (2% at 35 dB L_{night} increasing to 20% at 40 dB L_{night}), a recommendation of reducing nightly aircraft noise exposure threshold levels to 35 dB L_{night} is desirable.

CHAPTER 5
Summary

5.1   This update report has summarised the main findings in aircraft noise and health effects research over the six-month period September 2022 - March 2023. The findings have focussed on cardiovascular disease, the effects of noise on children, an exploration into the processes of noise sensitivity and findings on road, railway and aircraft noise and sleep disturbance in Leipzig have been summarised. The area of environmental noise and health impacts continues to be an important and growing area internationally, and it is expected this will be further reflected by the presentation of new findings at the ICBEN 2023 congress, to be held in June.

CHAPTER 6
References

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