Civil Aviation Authority

Aircraft Noise and Health Effects – a six monthly update

CAP 2328

Published by the Civil Aviation Authority, 2021

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West Sussex

RH6 0YR

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The latest version of this document is available in electronic format at www.caa.co.uk

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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 September 2021 – March 2022. 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. The authors would like to thank Bernard Berry (Bel acoustics) for his valued contribution to the source material.

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

Chapter 2

Aircraft Noise and Annoyance

2.1 This chapter summarises the main findings on aircraft noise and annoyance that have been published during the past six months.

2.2 Preisendörfer et al published a paper on annoyance responses to residential and aircraft noise in the two European cities Mainz in Germany and Zurich in Switzerland. The study examined both acoustic and non-acoustic factors that may affect indoor annoyance. The study examined the environmental concern in participants, and the link between income and annoyance to road and aircraft noise.

2.3 The paper discusses the most important acoustic factor, the objective exposure to noise, predominantly measured as the day-evening-night level (L_{den}). The most prominent non-acoustic factor is noise sensitivity, usually seen as a personality trait. Besides sociodemographic variables (gender, age, etc.), attitudes toward the noise source have been shown to be relevant for annoyance responses. Fear of harm connected with the noise source, individual coping capacity, and expectations of the future noise development are other non-acoustic factors that have been studied as part of the annoyance relationship.

2.4 The study focussed on three main factors:

(1) The role of windows as a feature of the building where people live.

(2) The role of individual environmental concern as a general attitude; and

(3) The role of household income as an indicator of socioeconomic resources.

2.5 The first looks at an acoustic factor, the second two are related to non-acoustic factors. The study explores the role of windows in reducing noise annoyance in general, and the role of high-quality windows in particular. The baseline hypothesis is that windows are an important barrier against outdoor residential noise and serve simultaneously as a subjective coping tool with noise. Closing windows can reduce indoor noise, and it may additionally be important for the subjective evaluation of the capacity to cope with noise (with windows as a tool to control the noise situation).

2.6 The authors explain that the growing environmental awareness of the public, and the increasing political attention to environmental protection have contributed to categorising noise issues under the broader umbrella of environmental problems. They liken the reaction to the effects of passive smoking to the way the public may take information on the negative health effects of noise more seriously now than in the past.

2.7 Environmental concern is a general attitude relating to affective worries about environmental protection, to cognitive insights into the endangerment of the environment, and to support for environmental action The authors explain that the general mindset of a high environmental concern can stimulate negative emotions toward noise as an environmental problem and thus result in stronger noise annoyance given the same level of noise exposure.

2.8 The relationship between income and noise annoyance can depend on local features, and the “environmental shielding hypothesis” focuses on how high-income households cope with noise and suggests several possibilities of noise protection. Sufficient income resources enable households to shield themselves against noise by using soundproofed high-quality windows. Apartments of resourceful households are usually larger than those of low-income households, with apartment size being important for locating living spaces and bedrooms away from road traffic noise. There might be a positive association between income and noise sensitivity, partly compensating the supposed negative income effect on noise annoyance.

2.9 Both cities are located near international airports. Mainz (with 210,000 inhabitants) is affected by Frankfurt Airport, which is about 25 km east of the city. Zurich (the largest city in Switzerland, with 430,000 inhabitants) is affected by Zurich Kloten Airport, which is about 10 km north of the city. Aircraft noise has been a controversial public issue in both cities for many years. Data were gathered as part of a project supported by the German Research Foundation (DFG) and the Swiss National Science Foundation (SNSF). The road traffic noise exposure L_{den} of the survey respondents is close to the WHO recommended limit of 53 dB L_{den}, both in Mainz (52.8 dB) and in Zurich (53.1 dB). The aircraft noise exposure is above the WHO recommended limit of 45 dB L_{den} in Mainz (46.5 dB) and slightly below the WHO limit in Zurich (44.3 dB).

2.10 Multivariate regression analysis was used to analyse the results, with the 11-point annoyance scale as the dependent variable. The results indicated that closed windows in general and closed high-quality windows in particular are an important barrier against outdoor road traffic and aircraft noise, as well as a helpful subjective coping tool against corresponding annoyances. Environmental concern, too, proves to be a significant predictor of noise annoyance.

2.11 Environmentally highly concerned people articulated feelings of annoyance more often than environmentally less concerned ones. As expected, income was negatively related to road traffic noise annoyance. However, a positive association of income with annoyance from aircraft noise was found. Although objective exposure to aircraft noise was lower for high-income households, they felt more strongly annoyed by noise from aircraft. Income shows various indirect effects on noise annoyance.

2.12 Marquis-Favre et al published a paper on combined road, rail and aircraft noise sources and a total annoyance model from field data. The study examined the annoyance in relation to combined noise sources using mixed models. The background to the study is that previously, studies looking at annoyance due to combined noise sources proposed different total annoyance models. These were very rarely assessed using field annoyance data. The authors explain that the aim of this study was to assess them using annoyance data from urban settings exposed to two or three combined transportation noise sources.

2.13 Ten classical total annoyance models were assessed and highlighted relevant existing models to account for combined transportation noise annoyance in cities. The results suggested that perceptual total annoyance models, based on annoyance due to each transportation noise source better performed the total annoyance calculation than psychophysical total annoyance models, which were based on the L_{den} index.

2.14 The results indicated that the dominant source effect mainly explained total annoyance responses from the residents, and the strongest component model led to a good calculation of mean total annoyance ratings. However, perceptual models with an interaction term, such as mixed models, better explained total annoyance judgements from respondents as they accounted for the contribution of each combined noise source and their interaction. The perceptual linear regression model was also interesting as it accounted for the contribution of each combined noise source and might be used for more than two combined noise sources. Those perceptual models accounted well for the resident feeling towards the different combined noise sources. The authors suggested that the results may provide a useful insight into studying the effects of combined noise sources and annoyance responses in the future.

2.15 Di et al looked at the role of noise sensitivity on perceived annoyance. This was not an aircraft noise-focussed study but given the importance of noise sensitivity as a non-acoustic factor in aircraft noise and annoyance studies, its findings may be relevant.

2.16 The study proposed a method to identify noise-sensitive individuals based on the experimental results of noise perceived annoyance, and the influence of noise sensitivity on perceived annoyance was also examined. 337 participants (undergraduate students) were recruited randomly. The noise sensitivity score (NSS) of each subject was obtained through the Weinstein's noise sensitivity scale. Using the ICBEN 11-point numerical annoyance scale, perceived annoyance in relation to noise (14 pink noise[1] samples) was examined in a

[1] Pink noise consists of all frequencies heard by humans, but the energy is not distributed equally across them. It is more intense at lower frequencies, which creates a deeper sound than e.g. white noise.

soundproof room. The subjects were divided into several groups according to the NSS of each subject.

2.17 The subjects were divided into several groups according to the NSS of each subject. According to the difference of perceived annoyance between different groups, a certain NSS was chosen as the threshold to identify high and low noise sensitive individuals. Results showed that the threshold was 110, i.e., the NSS of each high noise-sensitive individual was larger than or equal to 110 and the NSS of each low noise-sensitive individual was smaller than 110. Regression analysis revealed the effect of noise-sensitivity as a factor on perceived annoyance was up to 26%. The authors suggest that these results assist in determining the influence of noise sensitivity on perceived annoyance and highlight the importance of noise sensitivity as a non-acoustic factor.

Chapter 3

Aircraft noise and cardiovascular disease

3.1 Several publications detailed studies into aircraft noise and cardiovascular effects. These findings are summarised in this chapter.

3.2 Wojciechowska et al published a paper on the association between blood pressure, arterial stiffness, and aircraft noise in relation to a potential effect of the COVID-19 lockdown. The rationale for the study was that arterial hypertension is well recognised as one of the negative health consequences of environmental noise. The stress reaction to environmental noise is considered to be a primary causal link to hypertension development, and night-time noise exposure is yet more relevant for cardiovascular disorders, including hypertension, than noise exposure during daytime. Noise annoyance, along with the noise exposure level, has been shown to increase the risk of hypertension and cardiovascular disorders. Although previous research by Babisch and van Kamp has presented an exposure-response relationship per increase of 10 dB L_{den} and the associated relative risk of hypertension increasing by 13%, there has not been any evidence to suggest that a decrease in noise exposure would result in a corresponding lowering of risk of hypertension.

3.3 In a cross-sectional analysis of a case-control study in 2015, the same authors published the association between increased arterial stiffness (pulse wave velocity PWV) and aircraft noise exposure. In this study, the potential impact of a reduction in aircraft noise exposure on arterial stiffness in people previously exposed to increased aircraft noise was also investigated.

3.4 Residents living in two suburban areas of Krakow, Poland, were included in the study to obtain an equal number of participants exposed (>60 dB L_{den}) and unexposed (<55 dB L_{den}) to aircraft noise. Participants were aged between 40 and 65 years, which was considered optimal for assessing hypertension-mediated organ damage, and time of residence in the given area was a minimum of 3 years. All participants from the original investigation in 2015 were invited for a follow-up evaluation in June 2020, for assessment by the same study protocol, 74 participants in the exposed and 75 in the unexposed group were available for re-evaluation in 2020.

3.5 The study was conducted in an outpatient clinic of the University Hospital in Krakow during one visit. Office and 24-hour ambulatory Blood Pressure measurements (ABPM) were performed during the baseline visit and follow-up visit. ABPM measurements were taken every 15 minutes during the day (06:00–22:00 hours) and every 20 minutes during the night (22:00–06:00 hours). Hypertension was defined based on a prior diagnosis, or use of antihypertensive

treatment, or elevated office systolic BP (SBP) or diastolic BP (DBP) values or elevated 24-hour SBP or DBP.

3.6 Self-reported questionnaires on sleep quality and annoyance were also included, and to explore the potential influence of COVID-19 lockdown on studied parameters, the authors introduced additional items into the questionnaire by asking about lifestyle changes caused by the lockdown.

3.7 During the follow-up period between 2015 and March 2020, the exposure to aircraft noise remained constant in the exposed group. In contrast, a marked decrease in the average aircraft noise level occurred in April 2020, resulting in a reduction from 61.7 to 47 dB L_{den} during the day and from 55.4 to 43.4 dB L_{den} during the night, as compared with April 2019. From April 2020, the formerly exposed group was exposed to aircraft noise levels similar to the control group. In the latter, the environmental noise exposure conditions did not change in the corresponding residential area and remained below <55 dB L_{den} throughout the entire follow-up period between 2015 and 2020.

3.8 The results indicated that during follow-up, a significant increase in BMI, the prevalence of hypertension and the percentage of patients treated with antihypertensive medications was observed in the group exposed to aircraft noise. The incidence of arterial hypertension in the exposed group tended to be higher. The exposed participants at follow-up reported significantly lower noise annoyance (p=0.006) in comparison to the baseline visit, but still had higher levels than the unexposed group (p=0.001). During follow-up, no significant changes were revealed in the unexposed group in comparison to the baseline visit.

3.9 Difficulties in falling asleep were more prevalent in the group exposed to aircraft noise compared with the control group at baseline (p=0.02). A significant increase in difficulty falling asleep at the follow-up visit was observed in both studied groups. At baseline, >40% of the subjects in the exposed group reported awakenings at night, compared with only 24% in the unexposed group. However, this difference between groups in awakening during the night was no longer significant at the follow-up visit during the lockdown period. Similarly, the significantly higher prevalence of reported fatigue during the day observed in the exposed group at baseline was not maintained at the follow-up visit. Self-reported lifestyle parameters and working habits during the COVID-19 lockdown period did not change significantly as compared with the period before the lockdown in 2020, in either group.

3.10 During the baseline visit, participants in the exposed group had higher office and night-time DBP, as well as higher central SBP and DBP, compared with the unexposed group. At follow-up, significant group differences in BP types were only detected for central SBP. At the follow-up visit, a substantial drop in BP was observed in participants from both groups. In the unexposed group, 24-hour

SBP, daytime SBP, and daytime DBP were lower at follow-up visit than during the initial measurements (p≤0.013). In participants exposed to aircraft noise, a significant decrease of DBP was observed for all measurement methods (p≤0.022), while a decrease of SBP was significant in averaged 24-hour values and during daytime measurements (p≤0.034). Figure 1 displays the regression analyses between PWV and age among untreated participants.

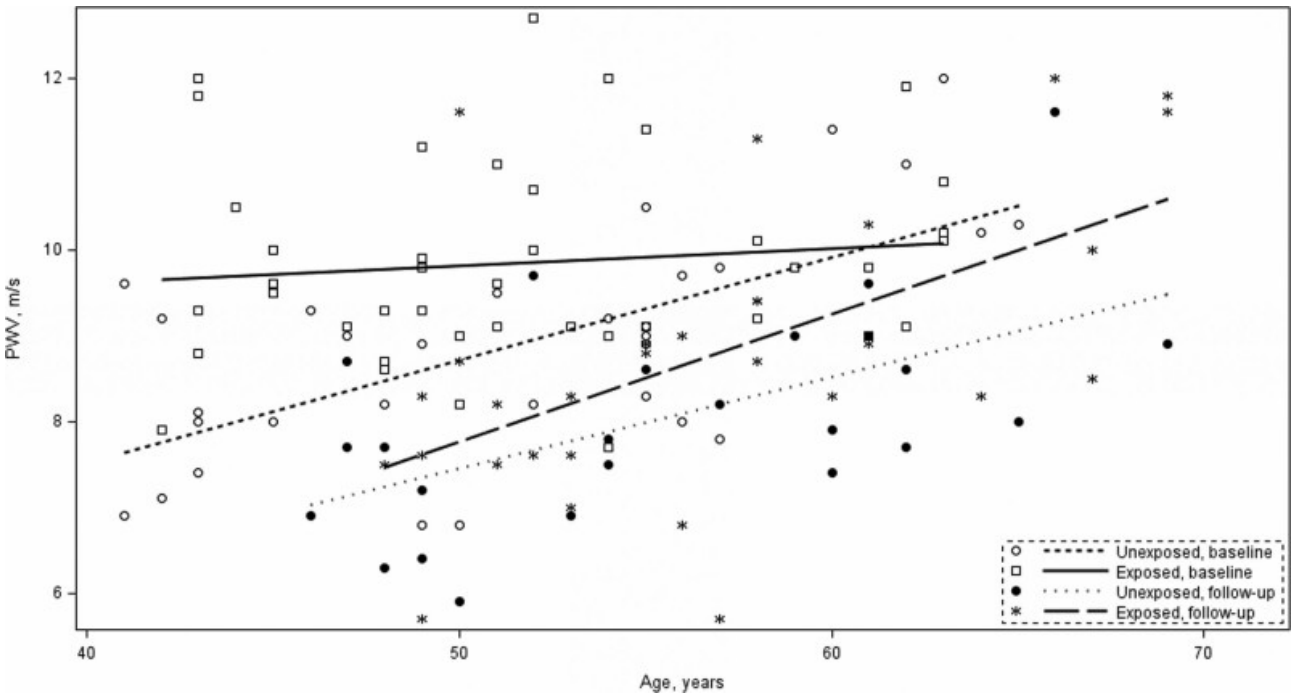

Figure 1: Unadjusted associations of pulse wave velocity (PWV) with age at baseline, and follow-up in untreated unexposed (Nbaseline=48; Nfollow-up=41) and exposed (Nbaseline =51; Nfollow-up=38) participants.

3.11 The results indicated that in the group exposed to aircraft noise at baseline no significant association was detected. In the unexposed group, a strong association was found. At the follow-up visit, a significant association between PWV and age was evident in the exposed group and was comparable to the unexposed group. However, the mean PWV in untreated participants remained still higher in the exposed than in the unexposed group.

3.12 The authors were interested in whether a short-term reduction in aircraft noise exposure caused by the COVID-19 lockdown may have beneficial effects on the increases in BP and arterial stiffness. Instead of progression in arterial stiffness, i.e., a further increase in PWV, as a result of aging and the 5 years aircraft noise exposure, a normalisation of the PWV was seen, which was previously elevated at baseline. In conclusion, the study suggests that long-term exposure to aircraft noise is associated with higher prevalence of arterial hypertension, while during

a short-term reduction in noise exposure due to the COVID-19 lockdown a significant decrease in PWV was observed. In addition, the natural relationship of PWV with age, previously skewed by noise exposure, was restored.

3.13 Rompel et al published a systematic review on the gender differences in health effects of environmental noise exposure on Ischaemic Heart Disease (IHD) and hypertension. The review explains that several pathophysiological pathways might play a role in cardiovascular morbidity induced by environmental noise. The most studied pathway is described by the noise reaction model. It is based on a chronic stress reaction and involves a direct response through agitation of the autonomic nervous system (fight/flight reaction), as well as an indirect endocrine response mediated by the hypothalamo–pituitary–adrenal (HPA) axis (defeat reaction). The HPA axis has been found to follow sex-specific response patterns and is influenced by the menstrual cycle and hormone status, which could be one reason why epidemiological studies partly find different noise effects for males and females. The authors state that biological differences between males and females cannot adequately explain health, disease, and exposure patterns alone. These patterns can also depend on gender-related factors determined by cultural, economic, and political conditions in society.

3.14 An explanation of sex as a biological construct, versus gender as a social construct is given in the review. Health research is increasingly recognising that both sex and gender needs to be integrated into future studies. The paper explains that in environment-related health research, however, the biological sex with its separate categories “males” and “females” is focused on, if at all, and gender is still largely neglected. The authors highlight the need for an overview of the current state of how sex/gender-aspects are taken into account in the investigation of the association of environmental noise and cardiovascular health, which was the aim of this review.

3.15 The search was restricted to long- and short-term studies in which sex/gender-specific analyses had been performed and were published between 2000 and 2020 in English or German language. Observational studies of any design (e.g., cohort, case-control, cross-sectional, case-crossover, or ecological) and road, railway and aircraft noise exposures were included. 30 studies were included in the review, with sample sizes ranging from 308 to 4.6 million people. Almost all of the studies were European, with two from India, one from North America and one from Korea. In all 30 studies included in the systematic review, sex/gender was described as a binary construct with the categories males/females or men/women.

3.16 In all 30 studies, sex/gender-theoretical concepts had not been considered in the study design nor in the discussion of sex/gender-specific results. Authors used the terms sex, gender, or both interchangeably, suggesting that they did not make a distinction between sex and gender or that they were not aware that

there is one at all. Additionally, most of the studies did not provide any information on how sex/gender of the participants was collected. The authors discuss how uncertainty in the way “sex” and/or “gender” was assessed has a major influence on the interpretation of results. It leads to confusion as to whether different effects between males and females are due to differences in their physiological profile, or in social and economic factors. Consequently, it becomes challenging for appropriate measures for health care and protection to be derived.

3.17 The authors conclude that the review indicates that cardiovascular risk due to environmental noise may differ between males and females. However, identified studies did not properly include sex/gender of the participants in the analysis, or could not do so due to unavailable data. Therefore, it remains unclear if observed effects result from differences in sex-related biology, gender-related factors, or from a combination of both. They suggest this highlights the need to take sex/gender-theoretical concepts into account in the planning phase of data collection to increase the validity of research findings, therefore making them more useful for prevention efforts, health promotion, and health care.

3.18 Thacher et al studied the long-term exposure to transportation noise and risk for atrial fibrillation in a Danish nationwide cohort study. Atrial fibrillation is a heart condition that causes an irregular and often abnormally fast heart rate that can lead to blood clots in the heart. The rationale for the study was that although epidemiological studies have found associations between transportation noise and various cardiovascular diseases (CVD), including hypertension, atrial fibrillation (AF) has received limited attention, despite being a prevalent disease, affecting around 4% of those >50 years old, and being a significant risk factor for stroke and Myocardial Infarction (MI).

3.19 The authors explain that the majority of studies on noise and health effects focus on exposure at the loudest or most exposed façade. However, many dwellings have a quieter façade, which is likely where a bedroom would be situated. Since sleep disturbance is potentially on the pathway from noise to AF, the hypothesis is that transportation noise at the least exposed façade might be relevant with regard to AF. The study aimed to investigate the association between long-term exposure to residential road traffic and railway noise at the most and least exposed façades and risk for AF in a nationwide cohort in Denmark. Aircraft noise exposure was also included in the analyses.

3.20 Road and railway noise (L_{den}) was estimated at the most and least exposed façades for all residential addresses across Denmark between 1990–2017. Time-weighted mean noise exposure was estimated for 3.6 million individuals age ≥35 years. Of these, 269,756 incident cases of AF were identified with a mean follow-up of 13.0 years.

3.21 The results indicated that a 10 dB higher 10-year mean road traffic noise at the most and least exposed façades were associated with incidence rate ratios (IRR) and 95% confidence intervals (CI) for AF of 1.006 (1.001–1.011) and 1.013 (1.007–1.019), respectively. After further adjustment for air pollution, measured by PM2.5, the IRRs (CIs) were 1.000 (0.995–1.005) and 1.007 (1.000–1.013), respectively. For railway noise, the IRRs per 10 dB increase in 10-year mean exposure were 1.017 (1.007–1.026) and 1.035 (1.021–1.050) for the most and least exposed façades, respectively, and were slightly attenuated when adjusted for PM2.5. Aircraft noise between 55 and 60 dB and ≥60 dB L_{den} were associated with IRRs of 1.055 (0.996–1.116) and 1.036 (0.931–1.154), respectively, when compared to levels of <45 dB L_{den}.

3.22 The authors concluded that transportation noise seems to be associated with a small increase in AF risk, especially for exposure at the least exposed façade. The findings for aircraft noise suggested an association with AF among the highly exposed.

3.23 Vienneau et al published the results of a long-term Swiss study on transportation noise exposure and cardiovascular mortality. The Swiss National Cohort (SNC) is a longitudinal research platform, linking the former national decennial census and, since 2010, the annual Registry Based Census and structural surveys with the births, mortality and emigration registries.

3.24 The 15-year analysis in this study was based on SNC data from 01 January 2001 to 31 December 2015. In total, 7.28 million observations were available at baseline. Analysis was based on 4.1 million observations. The follow-up was divided equally into three periods to support time-varying analysis and evaluate potential time trends by incorporating calendar time. These three 5-year periods were also used as virtual sub-cohorts defined as:

- sub-cohort1 (2001–2005; adults 30+ years old),
- sub-cohort2 (2006–2010; 35+ years old) and
- sub-cohort3 (2011–2015; 40+ years old).

3.25 The main outcomes under investigation were definitive primary causes of death from all cardiovascular diseases (CVD), blood pressure-related (BP), ischemic heart disease (IHD), myocardial infarction (MI), heart failure (HF), all stroke, haemorrhagic stroke (HS), and ischemic stroke (IS).

3.26 Noise exposure data was developed in the framework of the SiRENE project (Short and Long Term Effects of Transportation Noise Exposure). It includes a Swiss-wide noise exposure database for 2001 and 2011 for the three major transportation noise sources (road traffic, railway and aircraft). For civil airports, aircraft noise exposure was calculated on a yearly basis using air traffic data along with acoustic footprints based on radar data per aircraft type and route.

Exposure for the military airport was derived from idealised flight paths, number of flights and approximate operation times.

3.27 Different adjustment models were applied to the data:

- Model 0 included the three noise L_{den} variables, age as time scale, and strata sex and period (i.e. 2001–2005, 2006–2010, or 2011–2015). Model 1 further included the individual-level covariates civil status, education level, mother tongue, nationality and quintiles of local-socio-economic position (SEP).
- Model 2 additionally included the area-SEP and unemployment rate.
- Model 3, the main model, included additional adjustment for air pollution in quartiles (Model 3 for PM2.5, Model 3b for NO_2 as a sensitivity analysis).
- Model 4 additionally adjusted for noise eventfulness at night from all sources combined – either in Model 4.1 using the intermittency ratio (IR) or Model 4.2 as the number of events.

3.28 The results indicated that in the full cohort, road traffic and railway noise were associated with an increased risk of mortality for all CVD, BP-related, IHD, MI and stroke in each of the analytical Models 1 to 3 with increasing confounder adjustment. For aircraft noise, most associations in Model 3 were not significant except for MI (1.040 [1.020–1.060] per 10 dB) and ischemic stroke (1.065 [1.021–1.111] per 10 dB). Also, compared to other noise sources, aircraft noise was more sensitive to adjustment for area-SEP, displaying higher Hazard Ratios in Model 2 than Model 1 (which included the individual-level confounders but not area-SEP).

3.29 Figure 2 indicates the associations between road traffic, railway or aircraft noise and all CVD and MI mortality. For aircraft noise, exposure–response associations were non-linear with the risk increase in the higher noise range above the 45 dB guideline limit (CVD, IHD, HF, stroke), or in the range below (BP-related, ischemic stroke).

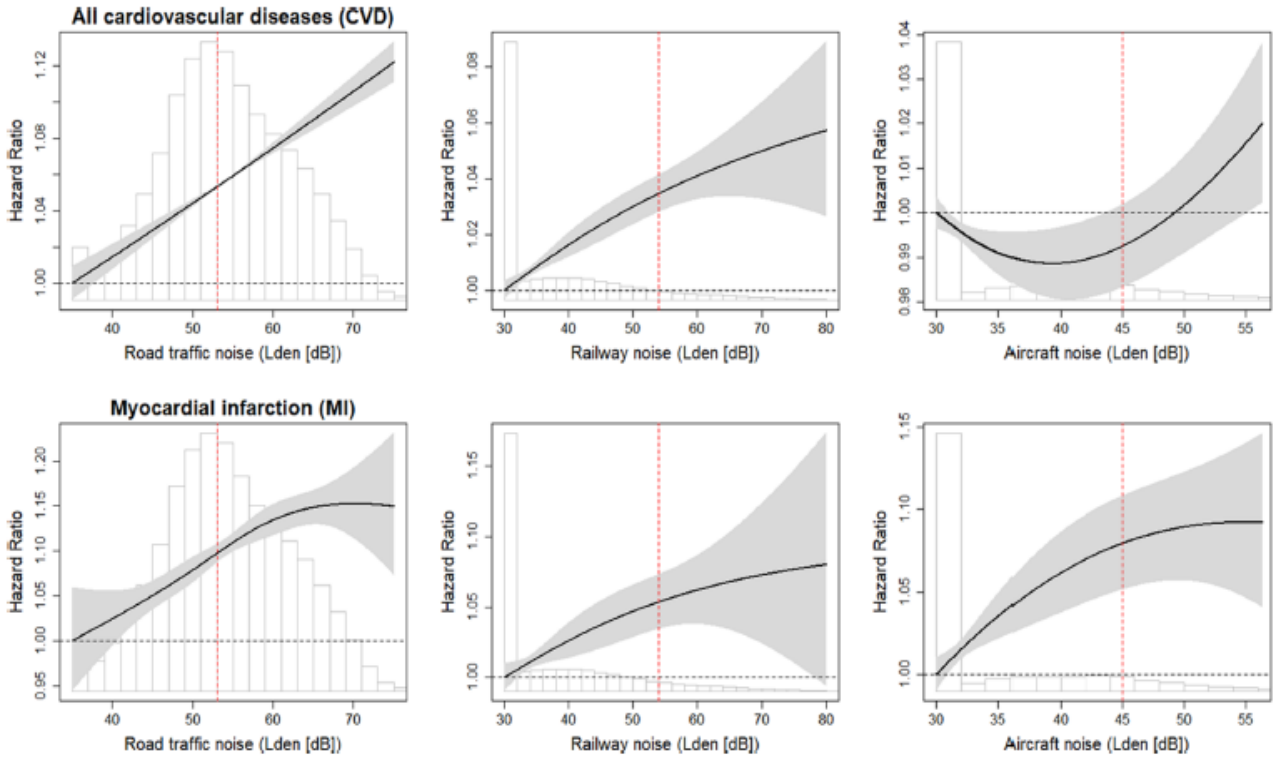

Figure 2: association between road traffic, railway or aircraft noise and all CVD and MI mortality. Multipollutant models, adjusting for the other two noise sources. Model 3: Included strata for sex and period, and adjusted for mother tongue, nationality, civil status, education, local Socio-Economic Position (SEP), area-SEP and unemployment, and PM2.5. Vertical red lines show WHO guideline levels based on L_{den}: road traffic = 53 dB, railway = 54 dB, aircraft = 45 dB L_{den}.

3.30 The risk of mortality associated with road traffic and railway noise was generally stronger in males compared to females for most outcomes, reaching statistical significance for road traffic noise exposure and CVD, BP, IHD, HF and stroke mortality. The pattern was not obvious for aircraft noise. The age stratified analyses showed the associations were often stronger in younger versus older ages, most consistently for all causes and road traffic noise exposure, though also apparent for CVD, IHD and MI with railway and/or aircraft noise exposure. The authors explain that while these higher relative risks were observed in younger adults, the absolute excess risk was highest in older adults as expected because of higher baseline cardiovascular mortality risk.

3.31 The authors concluded that independently of air pollution, road traffic and railway noise exposure were associated with the majority of CVD causes of death, often with risk increases starting well below the WHO guideline limits. They suggest that efforts to reduce or offer protection against excessive transportation noise should remain a priority to reduce the health burden from this leading environmental risk factor.

Chapter 4

Environmental noise exposure and children

4.1 This chapter highlights the recent work conducted into understanding the impacts of environmental noise on children and adolescents.

4.2 Bluhme et al published the results from a longitudinal study on the association between nocturnal transportation noise and sleep during the first year of life. The rationale for the study was that whilst the effects of transportation noise on sleep in adults are well studied, with impacts including reduced sleep duration, decreased self-reported quality, changes in sleep architecture with decreased proportions of deep sleep and increased sleep fragmentation, the impacts of such noise on infants remain not understood. This study investigated the relationship between nocturnal transportation noise and actimetry[2]-derived habitual sleep behaviour across the first year of life.

4.3 The study included 144 healthy infants (63 girls, 81 boys). Nocturnal (23:00–07:00) transportation noise (road, railway, and aircraft noise from major airports in Switzerland: Basel, Geneva, Payerne, Zurich) was modelled at the infants' individual places of residence. Annual means of equivalent continuous sound pressure levels (L_{Aeq}) were modelled for the geographical coordinates of each participant's place of residence. Using actimetry, the authors recorded movement patterns for 11 days in a longitudinal design at 3, 6, and 12 months of age and measured the sleep composites of night-time sleep duration, activity, and variability.

4.4 The results indicated that night-time transportation noise was unrelated to sleep composites across the first year of life ($p>0.16$). Further analyses of an interaction between noise and the existence of siblings indicated an association between night-time transportation noise and sleep duration in infants without siblings only ($p=0.004$).

4.5 The authors explain that the data provides novel evidence that infants' objectively assessed sleep during the first year of life generally seems well-protected against external disturbance, for instance by nocturnal transportation noise. However, individual noise sensitivity varies, and those infants who grow up in a sleep protective environment (for instance without noise from siblings) may be more sensitive to the adverse effects of transportation noise on sleep.

[2] Actigraphy is a non-invasive method of monitoring human rest/activity cycles, via a wrist-watch unit worn like a watch.

4.6 Raess et al studied the association between community noise and children's cognitive and behavioural development in São Paulo, Brazil. The authors explained that although noise exposure has been associated with adverse cognitive and behavioural outcomes in children, evidence on longitudinal associations between community noise and child development in low- and middle-income countries is rare. The study investigated associations between community noise and behavioural and cognitive development in pre-school children between three and six years old.

4.7 Child development data from the São Paulo Western Region Birth Cohort was linked with average 24-hour (L_{den}) and night-time (L_{night}) community noise exposure at children's homes, estimated by means of a land use regression model using various predictors (roads, schools, greenness, residential and informal settlements). The Strengths and Difficulties Questionnaire (SDQ) and Regional Project on Child Development Indicators (PRIDI) were the measured outcomes at 3 years of age and the Child Behaviour Checklist (CBCL), and International Development and Early Learning Assessment (IDELA) were the outcomes at 6 years of age. Regression models were used to examine the relationship between noise exposure and development.

4.8 Data from 3385 children at 3 years of age and 1,546 children at 6 years of age were analysed. The mean L_{den} and L_{night} levels were 70.3 dB and 61.2 dB, respectively. The results indicated that a 10 dB increase of L_{den} above 70 dB was associated with a 32% increase in the odds of borderline or abnormal SDQ total difficulties score (OR = 1.32, 95% CI: 1.04; 1.68) and 0.72 standard deviation (SD) increase in the CBCL total problems z score (95% CI: 0.55; 0.88).

4.9 In longitudinal analyses, each 10 dB L_{den} increase was associated with a 0.52 SD increase in behavioural problems (95% CI: 0.28; 0.77) and a 0.27 SD decrease in cognition (95%-CI: 0.55; 0.00). The results above 60 dB L_{night} were similar. The authors conclude that the results indicate that exposure to community noise is not only associated with increased behaviour difficulties at both ages 3 and 6, but also predicts increases in behavioural difficulties as well as cognitive declines in this age window. The findings suggest that community noise exposure above 70 dB L_{den} and of 60 dB L_{night} may impair behavioural and cognitive development of preschool children.

4.10 Essers et al published findings on environmental noise exposure and emotional, aggressive, and attention-deficit/hyperactivity disorder (ADHD) -related symptoms in children from two cohorts in Span and the Netherlands. Although this study was not strictly an aircraft noise effects study, the authors looked at both road traffic noise exposure and also total noise exposure, which included aircraft noise, railway noise, road traffic and industry noise.

4.11 The rationale for the study was that previously, it has been suggested that children may be more susceptible to the effects of environmental noise

exposure, and a suggested biological mechanism for this highlights how environmental noise exposure during pregnancy can increase the levels of maternal stress hormones and influence the HPA, ultimately impacting the brain development of the child. Studies investigating the association between environmental noise exposure, mainly residential road traffic and aircraft noise, and emotional, aggressive, and ADHD-related symptoms in children often show varied results, with a lack of investigation into emotional and aggressive symptoms. The authors also explain that most studies focused primarily on the noise exposure during childhood, while pregnancy exposure could also be a relevant window since the developmental processes of the foetus might be influenced by noise exposure-induced maternal stress.

4.12 The aim of the study was to analyse the association between pre-natal and childhood environmental noise exposure and emotional, aggressive, and ADHD-related symptoms in children from the two cohorts. 534 children from the Spanish cohort and 7,424 from the Netherlands cohort were included in the study. Average 24h noise exposure at the participants' home addresses during pregnancy and childhood periods were estimated using EU maps from road traffic noise and total noise. Symptom outcomes were assessed using validated questionnaires at 4, 7 and 9 years (Spanish group) and 18 months, 3, 5, and 9 years (Netherlands group).

4.13 The results indicated that average pre-natal and childhood road traffic noise exposure levels were 61.3 dB L_{den} and 61.7 dB L_{den} for the Spanish group and 54.6 dB L_{den} and 51.6 dB L_{den} for the Netherlands cohort, respectively. Pre-natal and childhood road traffic noise exposure were not associated with emotional, aggressive, or ADHD-related symptoms. No significant differences were observed between the two cohorts, and results were comparable for total noise exposure.

4.14 The authors concluded that no association was observed between pre-natal and childhood environmental noise exposure and emotional, aggressive, and ADHD-related symptoms in children in the two European cohorts. They explained that their analyses using longitudinal data and information from multiple noise sources showed a lack of associations in line with previous research that found no association with emotional or aggressive symptoms, but not with research that more consistently showed symptom outcomes in children. They suggest that future studies should include a more comprehensive noise exposure assessment considering noise sensitivity and noise exposure at different settings such as work for pregnant women and school for children.

4.15 Tangerman et al. looked at behavioural problems in adolescents and their exposure to road noise in Switzerland. The Strength and Difficulties Questionnaire (SDQ) was used to measure outcomes relating to emotional

problems, conduct problems, hyperactivity/inattention problems, peer relationship problems and pro-social behaviour.

4.16 There were two waves of data collections with two cohorts of participants (cohort 1: N = 442; cohort 2: N = 457). Both cohorts were subject to the same measurements with a baseline and a follow-up with a year in between measurements (cohort 1 baseline: 2012/13, follow-up: 2013/14; cohort 2 baseline: 2014/15, follow-up: 2015/16). These two cohorts were subsequently combined into one (N = 899). The mean age at baseline was 14 years. The authors found some indications that road traffic noise is associated with problem behaviour in adolescents, although associations were small compared to other factors. They suggest that further investigation should consider window orientation and longer follow-up times may be needed to observe longitudinal changes.

Chapter 5

Aircraft noise and cognition

5.1 Thompson et al published an updated systematic review and meta-analysis of the evidence relating to noise pollution and human cognition. This is an update to a previous review by Clark and Paunovic in 2015, and the strength of evidence for associations was assessed using the GRADE (Grading of Recommendations, Assessment, Development and Evaluations) framework. The authors also conducted random-effects meta-analyses where suitable.

5.2 The authors provide an explanation on the definition and types of cognition. Cognition refers to the faculties involved in acquiring, processing, using, and producing information and understanding, and includes attention, memory, learning, executive function, reasoning, computation, and language. Cognitive ability also relates to health, success, mental health, and wellbeing. Environmental noise exposure is thought to act as a distraction, and therefore affect learning, sleep, stress and learned helplessness.

5.3 The PECOS (participants, exposure, control/comparison, outcomes, and study design) statement for this study were:

- Participants: human populations across the lifespan.
- Exposure: environmental noise (exposure to noise in day-to-day life, as opposed to noise presented in a lab to measure concurrent effects on cognition).
- Control/Comparison: persons less exposed (continuously or in high/low exposure groups).
- Outcomes: non-pathological cognitive abilities.
- Study Design: epidemiological study designs, cohort, case-control and observational studies.

5.4 16 studies were identified and reviewed alongside 32 studies previously reviewed by Clark & Paunovic (2018). One of the 16 new studies included aircraft noise, with 20 of the studies reviewed by Clark and Paunovic including aircraft noise. The individual studies are described in detail in the report. In summary, the findings indicated that:

- moderate quality evidence that noise exposure (especially aircraft noise) was associated with reading and related abilities in children. A meta-analysis from 3 studies found that reading comprehension scores in quiet

classrooms were 0.80 (95% confidence interval: 0.40; 1.20) points higher than children in noisier classrooms.

- moderate quality evidence that executive function was not associated with aircraft noise in children, but evidence for other noise associations was low or very low quality (poor quality research or insufficiently investigated).

5.5 More research is required for outcomes such as general cognition and IQ, processing speed/reaction time, psychomotor abilities, and language/reading abilities in adults. The literature on young-to-middle-aged adult populations was scarce and inconclusive for all outcomes. Figure 3 illustrates the main findings of this review.

	Children	Adults
Academic ability	✓	✓
Attention	✓	✓
Memory and learning	✓	✗
Executive function	✗	✓
Reading and language	✓	✓
Fluid intelligence and general cognition	✓	50/50
Cognitive impairment	n/a	✓
Perceptual speed	n/a	✓

Associated in literature: ✓

Not associated in literature: ✗

High Quality evidence

Moderate Quality evidence

Low Quality evidence

Very low quality evidence

Figure 3: Summary of direction (supportive or not supportive) and rating of confidence (high, moderate, low, very low) in evidence for associations between environmental noise and cognitive outcomes.

5.6 The authors concluded that the evidence suggests that noise exposure is associated with cognition, but more good quality research using standardised methodology is required to corroborate these results. There is also a need for more research with older teenagers and young-to middle aged adults, on the co-variate effects of noise and air pollution, and in Africa, Central and South America, South Asia and Australasia.

Chapter 6

Summary

6.1 This update report has summarised the main findings in aircraft noise and health effects research over the six-month period September 2021 – March 2022. The findings have focussed on annoyance, cardiovascular disease, the effects of noise on children and adolescents, and cognition. 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 Internoise 2022 congress, to be held in August.

Chapter 7

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