UK Health Security Agency

Heathrow Noise and Airspace Community Forum

Current understanding of aviation noise impacts on health from scientific research

27 September 2023

Dr. Benjamin Fenech

Declaration of interests

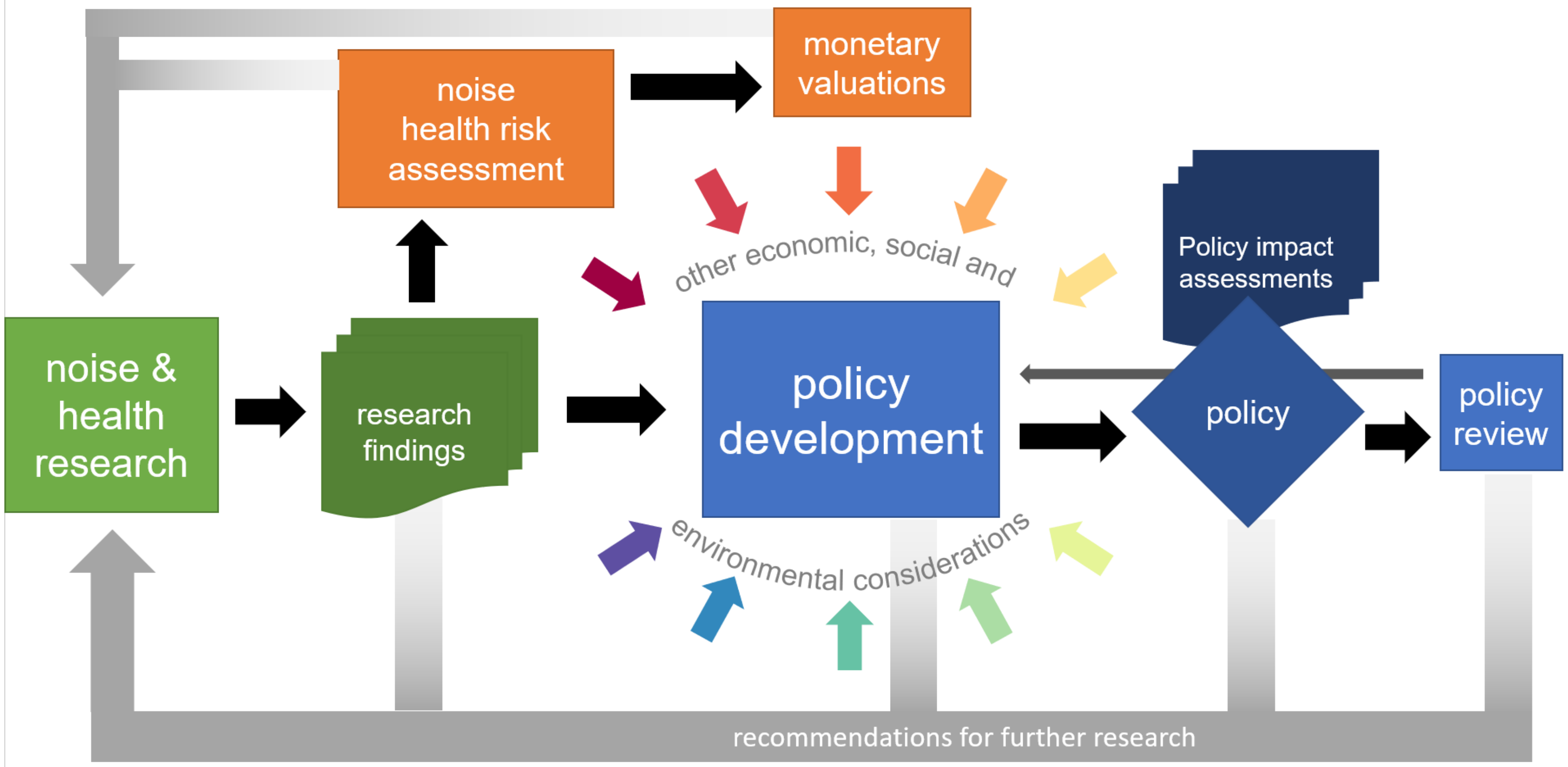
- Group leader, Noise and Public Health, UK Health Security Agency
- Member of Interdepartmental Group on Costs and Benefits (noise subgroup) – IGCB(N)
- Advisory member of ANEG, chair of ANEG-Heath subgroup
- Chair of advisory board to ANCO[1] and RISTANCO[2]
- Programme leader of ISO/TC 43/SC 1/WG 68 Non-acoustic factors
- Elected member of Institute of Acoustics Council, chair of Sound Noise & Health special interest group
- Chair of ICBEN[3] Team 9 (Policy and Economics)

[1] Aircraft Noise and Cardiovascular Outcomes

[2] Reduced noise Impacts of Short-Term Aircraft Noise and Cardiovascular Outcomes

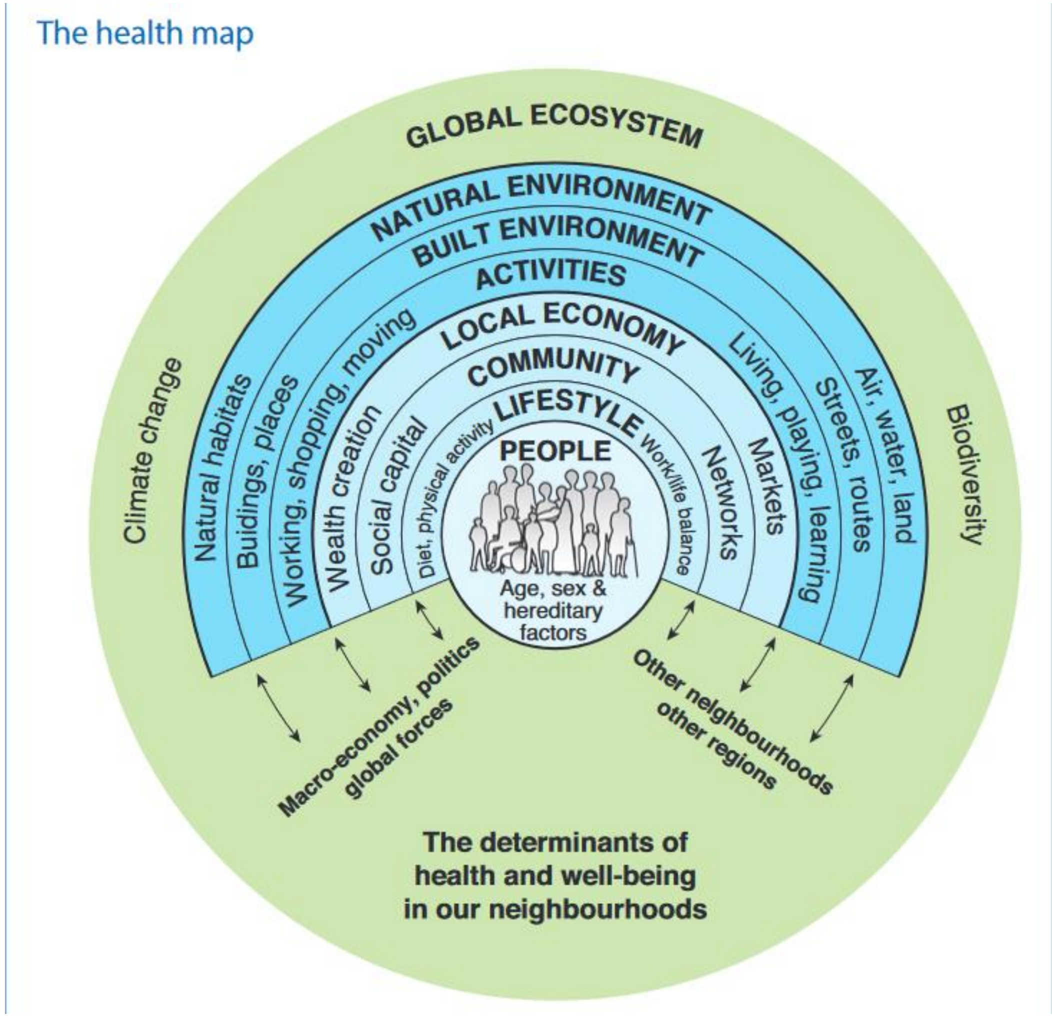
[3] International Commission on Biological Effects of Noise

Research to policy & practice



Adapted from Fenech and Janssen (2023) In *Proceedings to 14th ICBEN Congress on Noise as a Public Health Problem* (in press)

Framing the conversation about health



Barton, H., & Grant, M. (2006). A health map for the local human habitat. *Journal of the Royal Society for the Promotion of Health, 126*(6), 252–253.

Noise and health – mechanisms

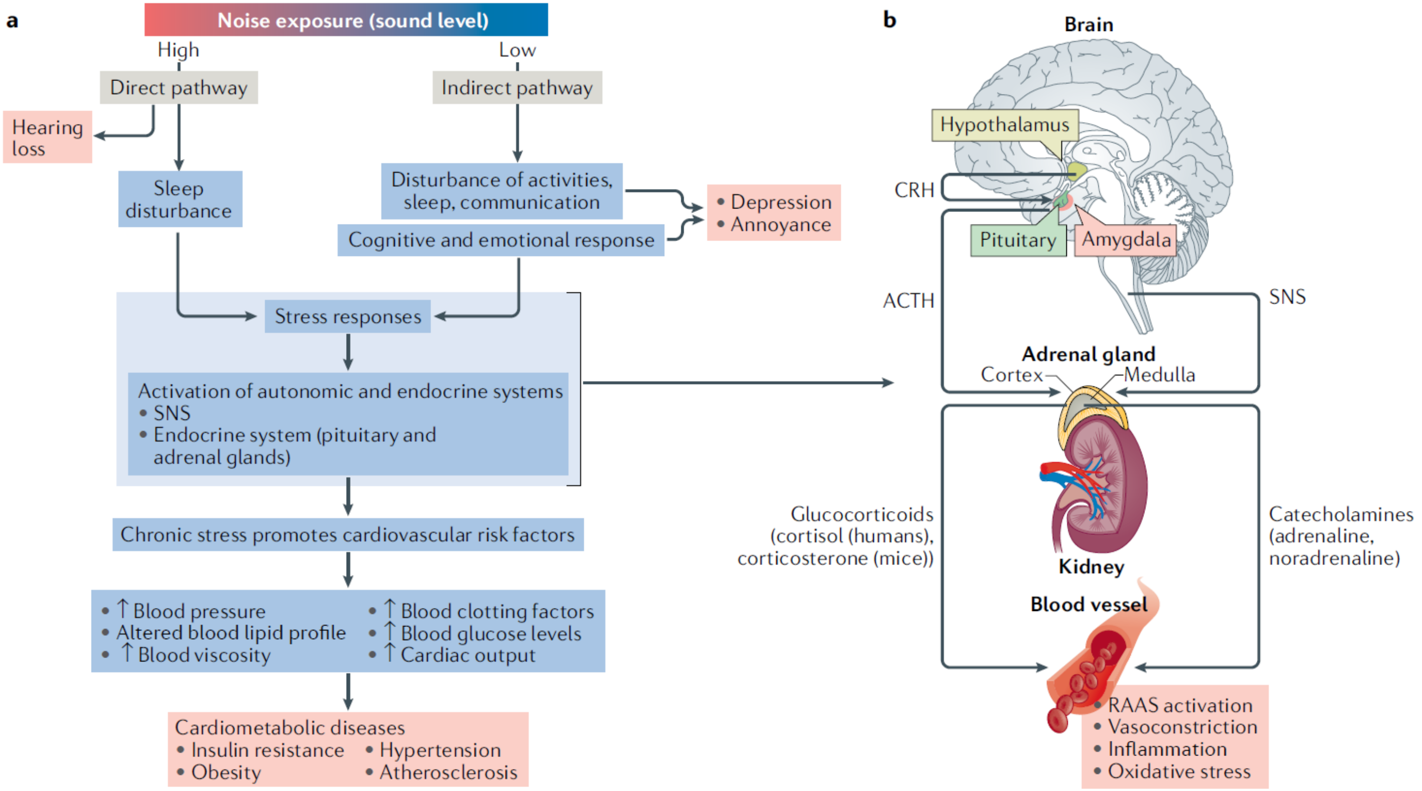


Fig. 3 | **Noise–stress concept and the adverse health consequences in humans. a** | Noise reaction model for the direct (auditory) and indirect (non-auditory) effects of noise exposure[173]. **b** | Neuronal activation (arousals) induced, for example, by noise exposure triggers signalling via the hypothalamic–pituitary–adrenal axis and sympathetic nervous system (SNS). In the hypothalamic–pituitary–adrenal axis, the hypothalamus releases corticotropin-releasing hormone (CRH; also known as corticoliberin) into the pituitary gland, which stimulates the release of adrenocorticotropic hormone (ACTH) into the blood. ACTH induces the production of glucocorticoids by the adrenal cortex, and the activation of the SNS stimulates the production of catecholamines by the adrenal medulla. The release of glucocorticoids and catecholamines in turn leads to the activation of other neurohormonal pathways (such as the renin–angiotensin–aldosterone (RAAS) system) and to increased inflammation and oxidative stress, which can ultimately have adverse effects on cardiovascular function and molecular targets. Panel **a** reprinted with permission from REF.[173], Oxford University Press.

Münzel, T., Sørensen, M. & Daiber, A. Transportation noise pollution and cardiovascular disease. *Nat Rev Cardiol* **18**, 619–636 (2021). https://doi.org/10.1038/s41569-021-00532-5

Aviation noise and health – state of the evidence
A complex picture

Health outcome	Status	Health outcome / topic	Status
Annoyance – average, long term		Cognitive effects in children	
Annoyance – summer months		Cognitive decline in adults	
Annoyance – influence of NAFs		Mental health (depression, anxiety)	
Sleep disturbance – subjective		Wellbeing & Quality of Life	
Sleep disturbance – physiological		Reproductive outcomes	
Cardiovascular – IHD		Cancers	
Cardiovascular – hypertension		Population subgroups at higher risk	
Cardiovascular – stroke		Effectiveness of interventions 1. Reduced noise emissions	1
All-cause mortality		2. sound insulation	2
Metabolic – diabetes		3. respite	3
Metabolic – obesity		4. NAFs (compensation, communication, …)	4

NOTE: Colouring for demonstartion purposes only

NOTE: Colouring for demonstartion purposes only

Slide prepared by B. Fenech for ANEG-Health meeting 05.06.2023

NAF – Non acoustic factors, IHD – ischaemic heart disease

Noise annoyance

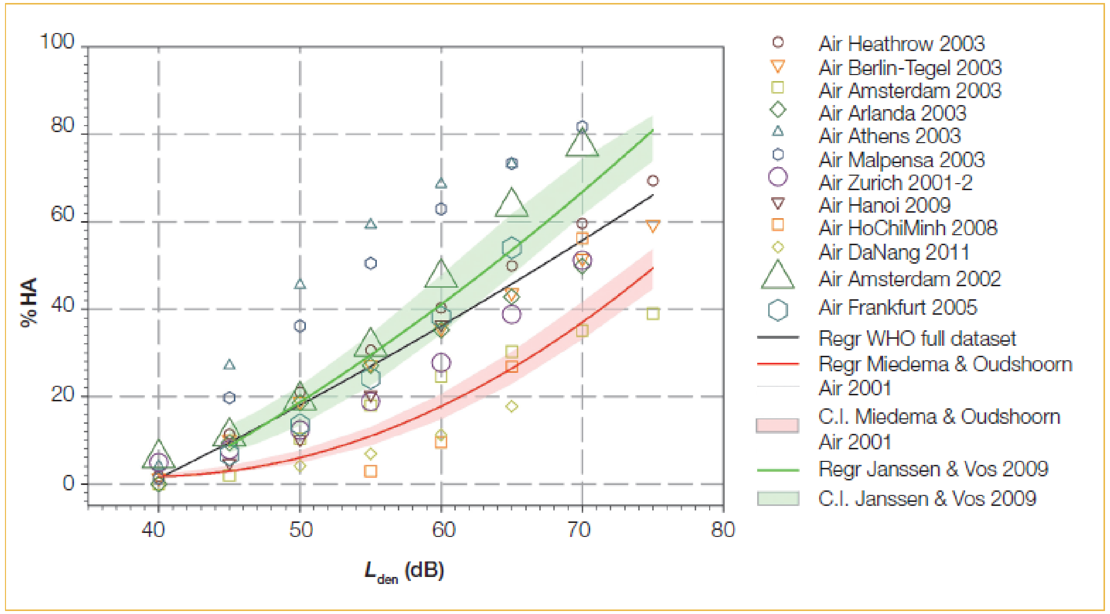
- Annoyance from aviation noise has been researched in detail for the past 50-60 years, and yet still a topic of active debate
- Easy to understand/relate to if you are impacted by noise
- Very difficult to explain to anyone else – complex concept (see for e.g.[1,2,3])
- Long-term high noise annoyance is considered a health endpoint as per the WHO definition of health, **BUT** no ICD[4] code
- Ongoing debate on the Disability Weight (for DALYs assessments)[5,6]
- Complex, bi-directional associations between annoyance and mental health[7]

[1] Guski, Felscher-Suhr, Schuemer (1999) Journal of Sound and Vibration (1999) 223(4), 513-527
[2] Guski, Schreckenberg, Schuemer (2014) Int. J. Environ. Res. Public Health 2017, 14(12), 1539; https://doi.org/10.3390/ijerph14121539
[3] Haubrich et al. (2019) ANIMA D2.4 - Recommendations on annoyance mitigation and implications for communication and engagement https://zenodo.org/record/3988131
[4] https://www.who.int/standards/classifications/classification-of-diseases
[5] https://apps.who.int/iris/handle/10665/326424
[6] https://www.rivm.nl/bibliotheek/rapporten/2018-0121.pdf
[7] Gong et al. (2022) Int. J. Environ. Res. Public Health 2022, 19(5), 2696; https://doi.org/10.3390/ijerph19052696

Aviation noise annoyance

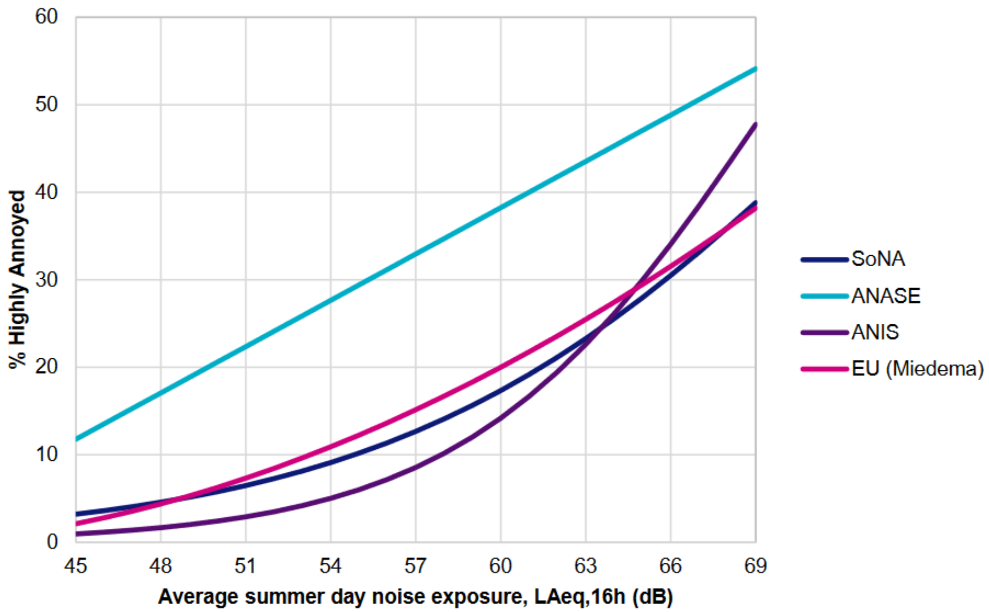
Which curve is ~~correct~~ most representative?

Fig. 13. Scatterplot and quadratic regression of the relationship between aircraft noise (L_{den}) and annoyance (%HA)



https://www.who.int/europe/publications/i/item/9789289053563

Figure 8: Comparison of % highly annoyed for SoNA 2014, ANASE, ANIS and Miedema



https://publicapps.caa.co.uk/modalapplication.aspx?appid=11&mode=detail&id=7744a

Interpreting findings from observational research

- ❑Internal validity – is the study believable?
- ❑External validity – are the results relevant to my situation?
- ❑Are statistical associations spurious, or a result of an indirect or direct effect?
- ➢No single study is perfect

Aviation noise annoyance

“Other types of uncertainty include … transferability of ERFs from locations where studies were carried out or data were otherwise gathered to another location. This is especially true for noise annoyance …. It is therefore not possible to determine the “exact value” of %HA for each exposure level in any generalized situation. Instead, **data and exposure–response curves derived in a local context should be applied whenever possible** ….”

WHO Environmental Noise Guidelines for the European Region 2018

WebTAG+

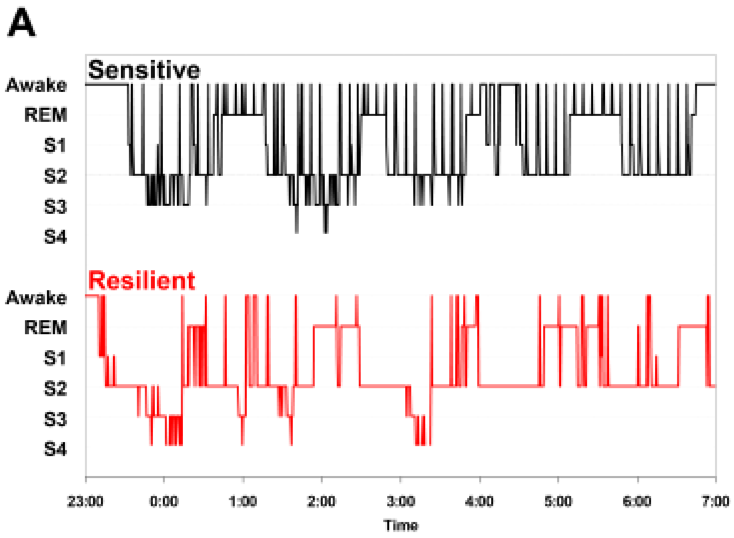
PHE welcomes the Applicant’s commitment to carry out sensitivity tests to supplement the results from the Department for Transport’s Web-based Transport Analysis Guidance (WebTAG) [49]. This is consistent with paragraph 2.1.2 of TAG Unit A3

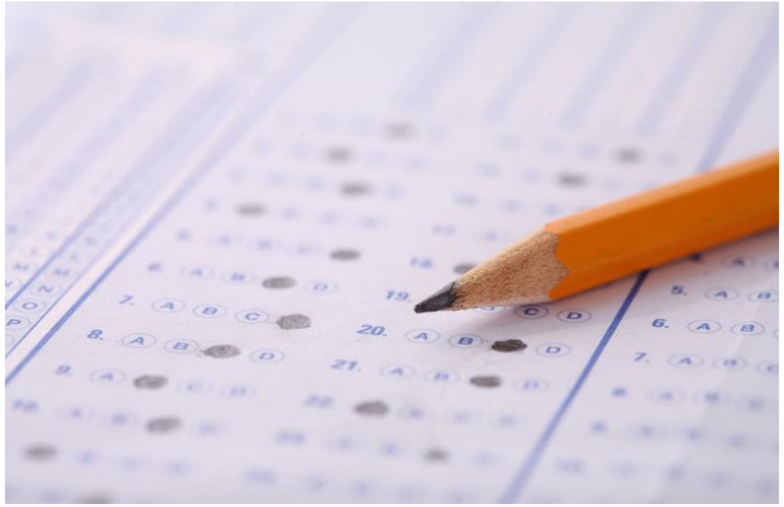
“Where noise impacts are particularly significant, sensitivity testing to reflect these various uncertainties may be required ….”

PHE’s preference is for WebTAG+ to include the ERF from Guski et al 2017 (WHO) [9] for aviation, to enhance the scope of the sensitivity tests.

Extract from Public Health England’s response to London Heathrow Airport Expansion Consultation - 18th June - 13th September 2019

Sleep disturbance

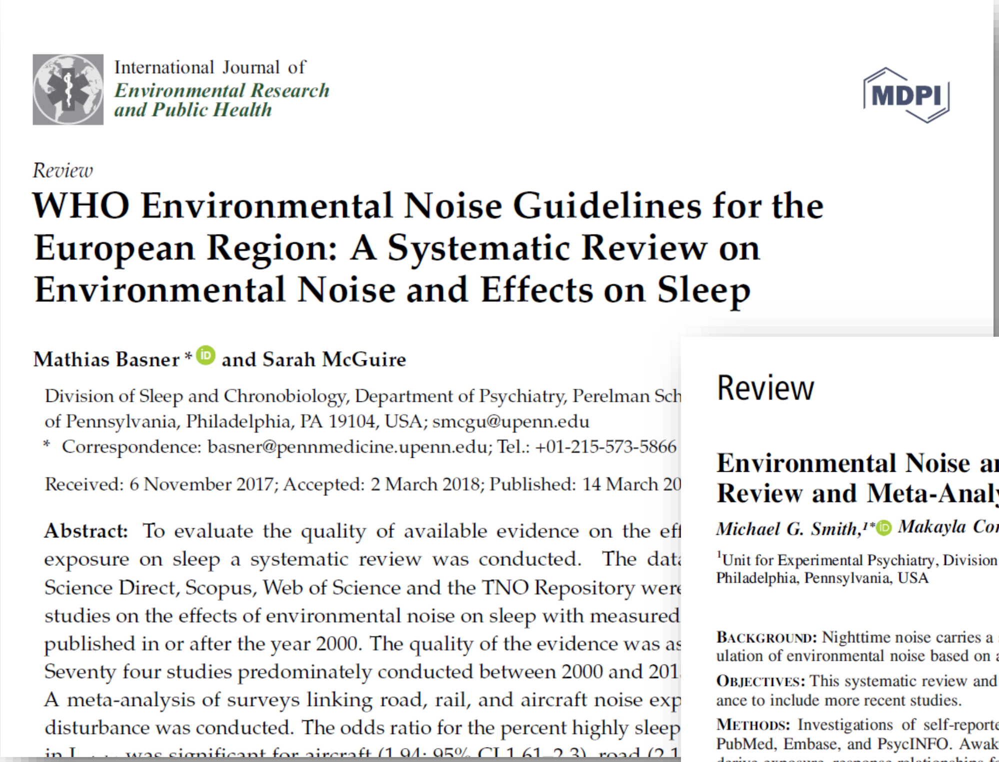




- Subjective vs objective – both give different but complimentary perspectives[1]
- Objective evidence gives mechanistic insight on importance of specific characteristics of the sound, timings, etc
- Subjective evidence provides insight on perceived impact on communities, including influence of non-acoustic factors

[1] Basner, M.; McGuire, S. (2018) *Int. J. Environ. Res. Public Health* 2018, *15*, 519

Sleep disturbance



International Journal of *Environmental Research and Public Health*

MDPI

Review

WHO Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and Effects on Sleep

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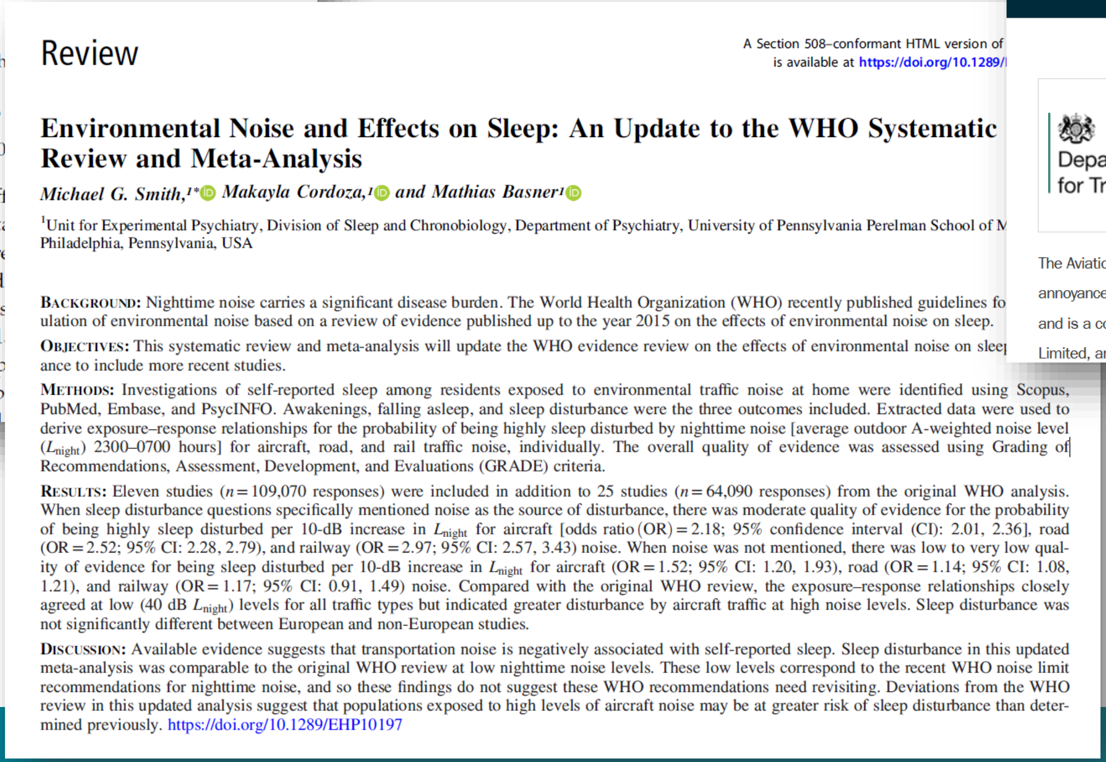
Abstract: To evaluate the quality of available evidence on the eff
exposure on sleep a systematic review was conducted. The data
Science Direct, Scopus, Web of Science and the TNO Repository were
studies on the effects of environmental noise on sleep with measured
published in or after the year 2000. The quality of the evidence was as
Seventy four studies predominately conducted between 2000 and 201
A meta-analysis of surveys linking road, rail, and aircraft noise exp
disturbance was conducted. The odds ratio for the percent highly sleep

Int. J. Environ. Res. Public Health **2018**, 15, 519; https://doi.org/10.3390/ijerph15030519



Review

A Section 508–conformant HTML version of
is available at https://doi.org/10.1289/

Environmental Noise and Effects on Sleep: An Update to the WHO Systematic Review and Meta-Analysis

Michael G. Smith,[1] Makayla Cordoza,[1] and Mathias Basner[1]*

[1]Unit for Experimental Psychiatry, Division of Sleep and Chronobiology, Department of Psychiatry, University of Pennsylvania Perelman School of M
Philadelphia, Pennsylvania, USA

Background: Nighttime noise carries a significant disease burden. The World Health Organization (WHO) recently published guidelines fo ulation of environmental noise based on a review of evidence published up to the year 2015 on the effects of environmental noise on sleep.

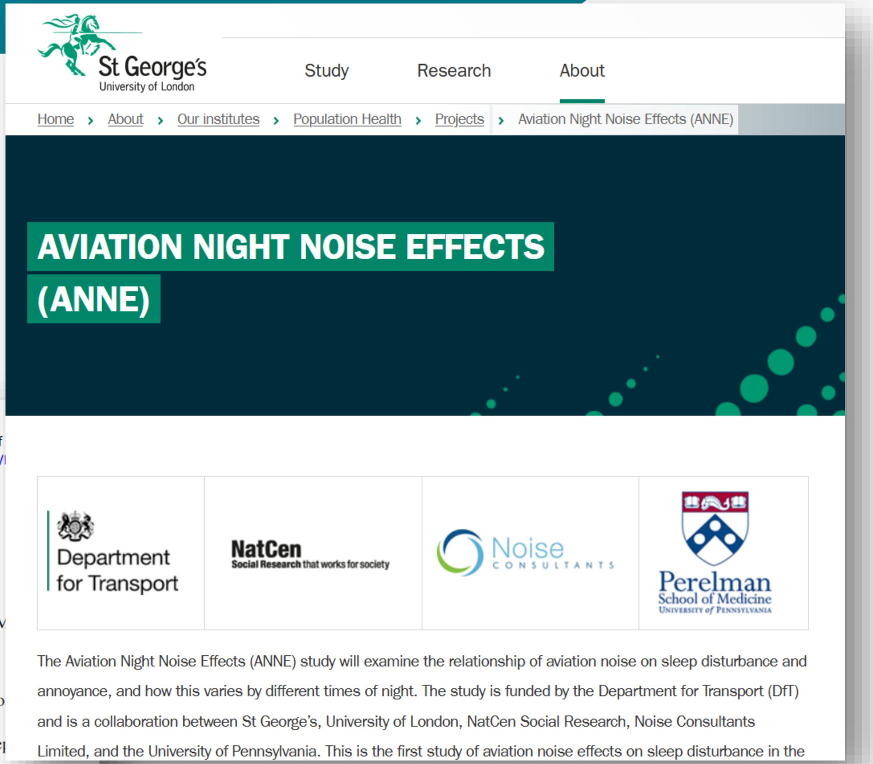
Objectives: This systematic review and meta-analysis will update the WHO evidence review on the effects of environmental noise on sleep ance to include more recent studies.

Methods: Investigations of self-reported sleep among residents exposed to environmental traffic noise at home were identified using Scopus, PubMed, Embase, and PsycINFO. Awakenings, falling asleep, and sleep disturbance were the three outcomes included. Extracted data were used to derive exposure–response relationships for the probability of being highly sleep disturbed by nighttime noise [average outdoor A-weighted noise level (L_{night}) 2300–0700 hours] for aircraft, road, and rail traffic noise, individually. The overall quality of evidence was assessed using Grading of Recommendations, Assessment, Development, and Evaluations (GRADE) criteria.

Results: Eleven studies ($n = 109{,}070$ responses) were included in addition to 25 studies ($n = 64{,}090$ responses) from the original WHO analysis. When sleep disturbance questions specifically mentioned noise as the source of disturbance, there was moderate quality of evidence for the probability of being highly sleep disturbed per 10-dB increase in L_{night} for aircraft [odds ratio (OR) = 2.18; 95% confidence interval (CI): 2.01, 2.36], road (OR = 2.52; 95% CI: 2.28, 2.79), and railway (OR = 2.97; 95% CI: 2.57, 3.43) noise. When noise was not mentioned, there was low to very low quality of evidence for being sleep disturbed per 10-dB increase in L_{night} for aircraft (OR = 1.52; 95% CI: 1.20, 1.93), road (OR = 1.14; 95% CI: 1.08, 1.21), and railway (OR = 1.17; 95% CI: 0.91, 1.49) noise. Compared with the original WHO review, the exposure–response relationships closely agreed at low (40 dB L_{night}) levels for all traffic types but indicated greater disturbance by aircraft traffic at high noise levels. Sleep disturbance was not significantly different between European and non-European studies.

Discussion: Available evidence suggests that transportation noise is negatively associated with self-reported sleep. Sleep disturbance in this updated meta-analysis was comparable to the original WHO review at low nighttime noise levels. These low levels correspond to the recent WHO noise limit recommendations for nighttime noise, and so these findings do not suggest these WHO recommendations need revisiting. Deviations from the WHO review in this updated analysis suggest that populations exposed to high levels of aircraft noise may be at greater risk of sleep disturbance than determined previously. https://doi.org/10.1289/EHP10197

Environmental Health Perspectives 130:7 CID: 076001 https://doi.org/10.1289/EHP10197



St George's University of London

Study | Research | About

Home › About › Our institutes › Population Health › Projects › Aviation Night Noise Effects (ANNE)

AVIATION NIGHT NOISE EFFECTS (ANNE)

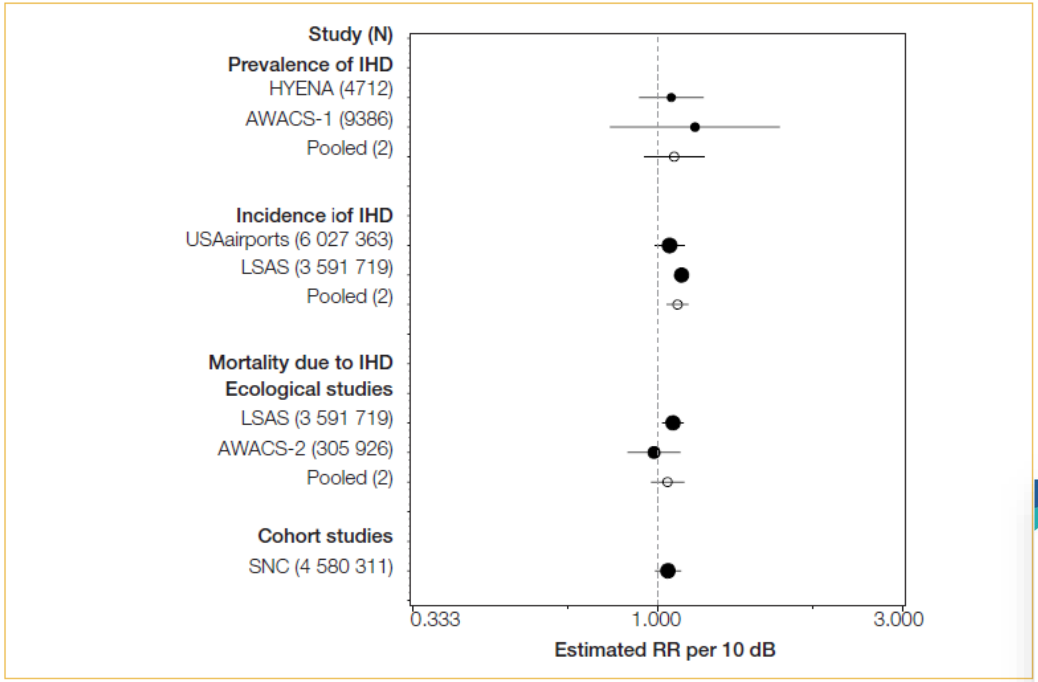
Department for Transport | NatCen Social Research that works for society | Noise Consultants | Perelman School of Medicine University of Pennsylvania

The Aviation Night Noise Effects (ANNE) study will examine the relationship of aviation noise on sleep disturbance and annoyance, and how this varies by different times of night. The study is funded by the Department for Transport (DfT) and is a collaboration between St George's, University of London, NatCen Social Research, Noise Consultants Limited, and the University of Pennsylvania. This is the first study of aviation noise effects on sleep disturbance in the

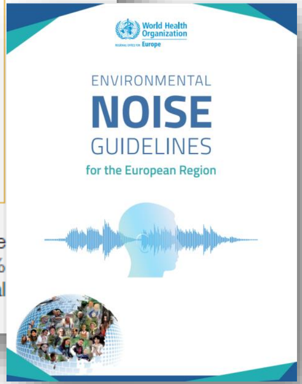
https://www.sgul.ac.uk/about/our-institutes/population-health/projects/aviation-night-noise-effects-study

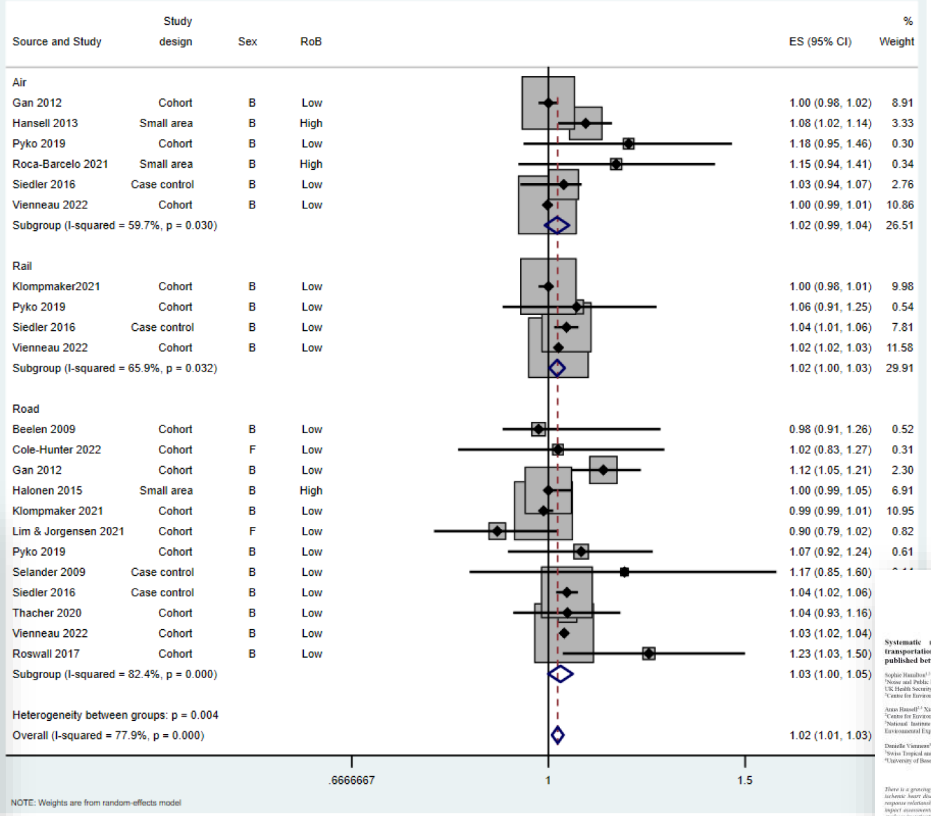
Cardiovascular disease

Fig. 10. The association between exposure to aircraft noise (L_{den}) and IHD



Notes: The dotted vertical line corresponds to no effect of exposure to aircraft noise. The black circles correspond to the estimated RR per 10 dB and 95% CI. The white circles represent the pooled random effect estimates and 95% CI. For further details on the studies included in the figure please refer to the systematic review on environmental noise and cardiovascular and metabolic effects (van Kempen et al., 2018).





Source and Study	Study design	Sex	RoB	ES (95% CI)	% Weight
Air					
Gan 2012	Cohort	B	Low	1.00 (0.98, 1.02)	8.91
Hansell 2013	Small area	B	High	1.08 (1.02, 1.14)	3.33
Pyko 2019	Cohort	B	Low	1.18 (0.95, 1.46)	0.30
Roca-Barcelo 2021	Small area	B	High	1.15 (0.94, 1.41)	0.34
Siedler 2016	Case control	B	Low	1.03 (0.94, 1.07)	2.76
Vienneau 2022	Cohort	B	Low	1.00 (0.99, 1.01)	10.86
Subgroup (I-squared = 59.7%, p = 0.030)				1.02 (0.99, 1.04)	26.51
Rail					
Klompmaker2021	Cohort	B	Low	1.00 (0.98, 1.01)	9.98
Pyko 2019	Cohort	B	Low	1.06 (0.91, 1.25)	0.54
Siedler 2016	Case control	B	Low	1.04 (1.01, 1.06)	7.81
Vienneau 2022	Cohort	B	Low	1.02 (1.02, 1.03)	11.58
Subgroup (I-squared = 65.9%, p = 0.032)				1.02 (1.00, 1.03)	29.91
Road					
Beelen 2009	Cohort	B	Low	0.98 (0.91, 1.26)	0.52
Cole-Hunter 2022	Cohort	F	Low	1.02 (0.83, 1.27)	0.31
Gan 2012	Cohort	B	Low	1.12 (1.05, 1.21)	2.30
Halonen 2015	Small area	B	High	1.00 (0.99, 1.05)	6.91
Klompmaker 2021	Cohort	B	Low	0.99 (0.99, 1.01)	10.95
Lim & Jorgensen 2021	Cohort	F	Low	0.90 (0.79, 1.02)	0.82
Pyko 2019	Cohort	B	Low	1.07 (0.92, 1.24)	0.61
Selander 2009	Case control	B	Low	1.17 (0.85, 1.60)	
Siedler 2016	Case control	B	Low	1.04 (1.02, 1.06)	
Thacher 2020	Cohort	B	Low	1.04 (0.93, 1.16)	
Vienneau 2022	Cohort	B	Low	1.03 (1.02, 1.04)	
Roswall 2017	Cohort	B	Low	1.23 (1.03, 1.50)	
Subgroup (I-squared = 82.4%, p = 0.000)				1.03 (1.00, 1.05)	
Heterogeneity between groups: p = 0.004					
Overall (I-squared = 77.9%, p = 0.000)				1.02 (1.01, 1.03)	

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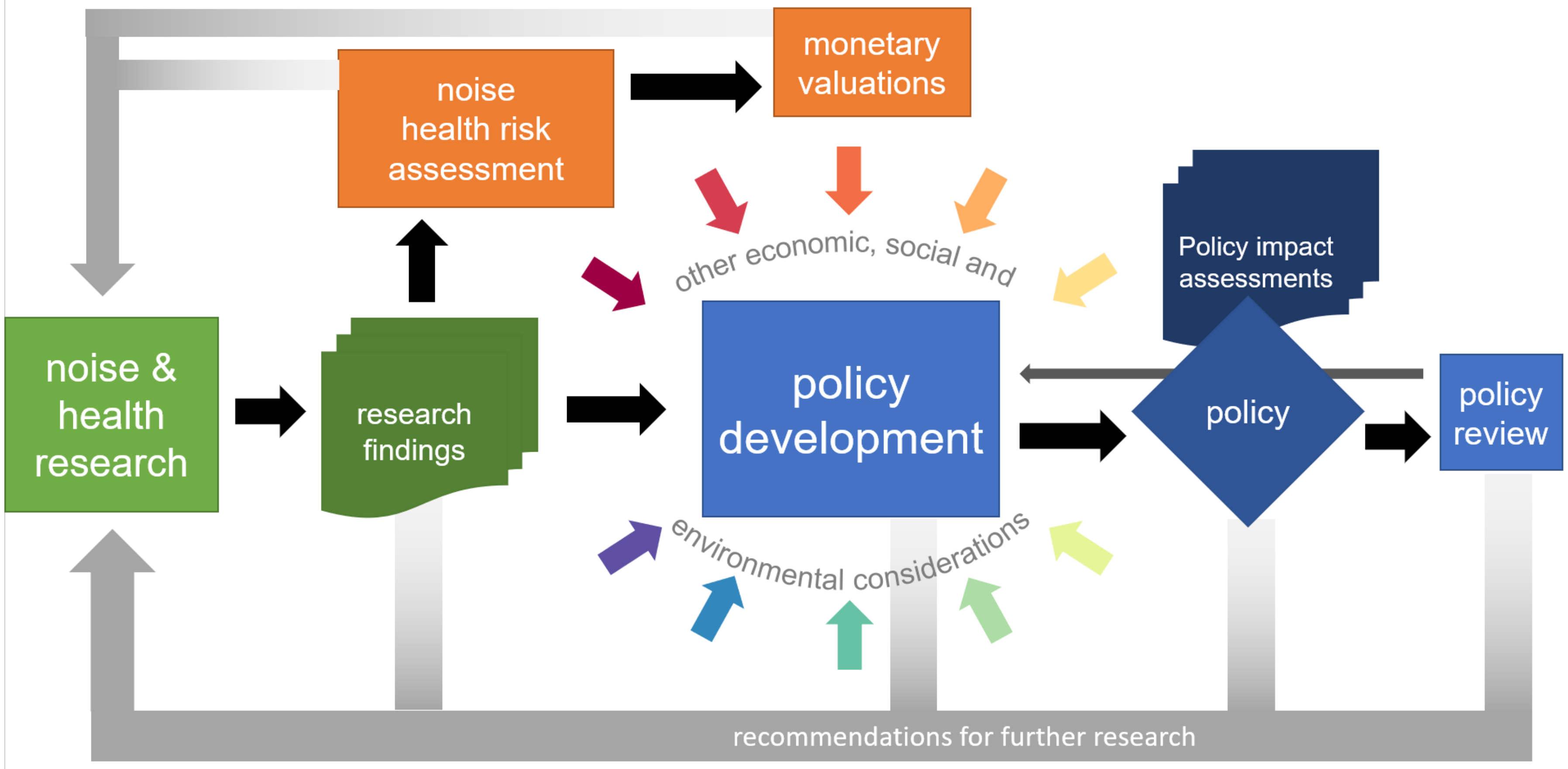
Research to policy & practice



Adapted from Fenech and Janssen (2023) In *Proceedings to 14th ICBEN Congress on Noise as a Public Health Problem* (in press)

Health risk assessments

“A health risk assessment is the scientific evaluation of potential adverse health effects resulting from human exposure to a particular hazard – in this case, environmental noise. The main purpose of the assessment is to estimate and communicate the health impact of exposure to noise or changes in noise in different socioeconomic, environmental and policy circumstances.”

WHO ENG 2018 p108


Environment International 178 (2023) 107966

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journal homepage: www.elsevier.com/locate/envint

Full length article

Spatial assessment of the attributable burden of disease due to transportation noise in England

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Environmental burden of disease
Environmental health

ABSTRACT

Background: Noise pollution from transportation is one of the leading contributors to the environmental disease burden in Europe. We provide a novel assessment of spatial variations of these health impacts within a country, using England as an example.
Methods: We estimated the burden of annoyance (highly annoyed), sleep disturbance (highly sleep disturbed), ischemic heart disease (IHD), stroke, and diabetes attributable to long-term transportation noise exposures in England for the adult population in 2018 down to local authority level (average adult population: 136,000). To derive estimates, we combined literature-informed exposure-response relationships, with population data on noise exposures, disease, and mortalities. Long-term average noise exposures from road, rail and aircraft were sourced from strategic noise mapping, with a lower exposure threshold of 50 dB (decibels) L_{den} and L_{night}.
Results: 40 %, 4.5 % and 4.8 % of adults in England were exposed to road, rail, and aircraft noise exceeding 50 dB L_{den}. We estimated close to a hundred thousand (~97,000) disability adjusted life years (DALY) lost due to road-traffic, ~13,000 from railway, and ~ 17,000 from aircraft noise. This excludes some noise-outcome pairs as there were too few studies available to provide robust exposure–response estimates. Annoyance and sleep disturbance accounted for the majority of the DALYs, followed by strokes, IHD, and diabetes. London, the South East, and North West regions had the greatest number of road-traffic DALYs lost, while 63 % of all aircraft noise DALYs were found in London. The strategic noise mapping did not include all roads, which may still have significant traffic flows. In sensitivity analyses using modelled noise from all roads in London, the DALYs were 1.1x to 2.2x higher.
Conclusion: Transportation noise exposures contribute to a significant and unequal environmental disease burden in England. Omitting minor roads from the noise exposure modelling leads to underestimation of the disease burden.

1. Introduction

Noise from road traffic, rail, and aviation transport affects millions of people in Europe (EEA, 2020) and are major contributors to the overall environmental disease burden (Hanninen et al., 2014; EEA, 2020). In England, the Environmental Noise Regulations 2006 (as amended) requires, on a five year cycle, the determination, through noise mapping, of exposure to environmental noise from major sources of road, rail and aircraft, and in urban areas (known as agglomerations) (HM Government, 2006). The Environmental Noise (England) Regulations 2006

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https://www.sciencedirect.com/science/article/pii/S0160412023002398?via%3Dihub

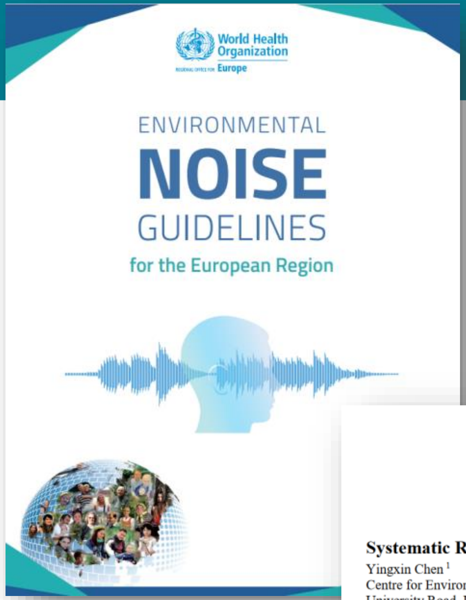
Health risk assessments

Table 1
Parameters used to estimate the burden of disease attributable to transportation noise for the adult population in England in 2018.

	Health outcome	Noise metric	ERR source	ERR function/relative risk estimate [95 % confidence interval]	ERR lower	ERR upper	Disability weight [95 % confidence interval *if available*]
Road	Highly annoyed	L_{den}	(Guski et al. 2017) *	$\%HA = 116.4304–4.7342 \times L_{den} + 0.0497 \times L_{den}^2$ *Excluding Asian and Alpine studies*	40 dB	80 dB	0.02 (WHO Regional Office for Europe 2011)
	Highly sleep disturbed	L_{night}	(Smith et al. 2022) **	$\%HSD = 31.18323 – 1.47351 \times L_{night} + 0.01851 \times L_{night}^2$	40 dB	65 dB	0.07 (WHO 2009)
	Ischemic heart disease	L_{den}	(van Kempen et al. 2018)	1.08 [1.01–1.15] per 10 dB	53 dB	80 dB	0.405 (WHO 2018)
	Stroke	L_{den}	(van Kempen et al. 2018)	1.14 [1.03–1.25] per 10 dB	50 dB	70 dB	0.522 [0.377–0.707] (Salomon et al. 2015)
	Diabetes mellitus	L_{den}	(Sakhvidi et al. 2018)	1.07 [1.02–1.12] per 5 dB	50 dB	80 dB	0.049 [0.031–0.072] (Global Burden of Disease Collaborators 2017)
Railway	Highly annoyed	L_{den}	(Guski et al. 2017)	$\%HA = 38.1596 – 2.05538 \times L_{den} + 0.0285 \times L_{den}^2$	40 dB	85 dB	0.02 (WHO Regional Office for Europe 2011)
	Highly sleep disturbed	L_{night}	(Smith et al. 2022) **	$\%HSD = 63.56140 – 3.00711 \times L_{night} + 0.03717 \times L_{night}^2$	40 dB	65 dB	0.07 (WHO 2009)
Aircraft	Highly annoyed	L_{den}	(Guski et al. 2017)	$\%HA = -50.9693 + 1.0168 \times L_{den} + 0.0072 \times L_{den}^2$	40 dB	75 dB	0.02 (WHO Regional Office for Europe 2011)
	Highly sleep disturbed	L_{night}	(Smith et al. 2022) **	$\%HSD = 17.07421 – 1.12624 \times L_{night} + 0.02502 \times L_{night}^2$	40 dB	65 dB	0.07 (WHO 2009)
	Ischemic heart disease	L_{den}	(van Kempen et al. 2018)	1.09 [1.04–1.15] per 10 dBA	47 dB	75 dB	0.405 (WHO 2018)

ERR: Exposure response relationship; ERR lower: Lowest noise level at which the ERR is considered valid; ERR upper: Highest noise level above which the risk stays constant.
*WHO commissioned systematic review derived two ERR curves for highly annoyed due to road-traffic noise exposure. One curve utilizing the full WHO dataset and another excluded Asian and Alpine studies (Guski et al. 2017).
**Smith et al presented multiple curves for HSD. We used the 'combined estimate' where noise was explicitly mentioned in the question (Smith et al. 2022).

https://www.sciencedirect.com/science/article/pii/S0160412023002398?via%3Dihub



inter.noise 2022
21-24 AUGUST SCOTTISH EVENT CAMPUS GLASGOW

Systematic Review of meta-analyses for noise

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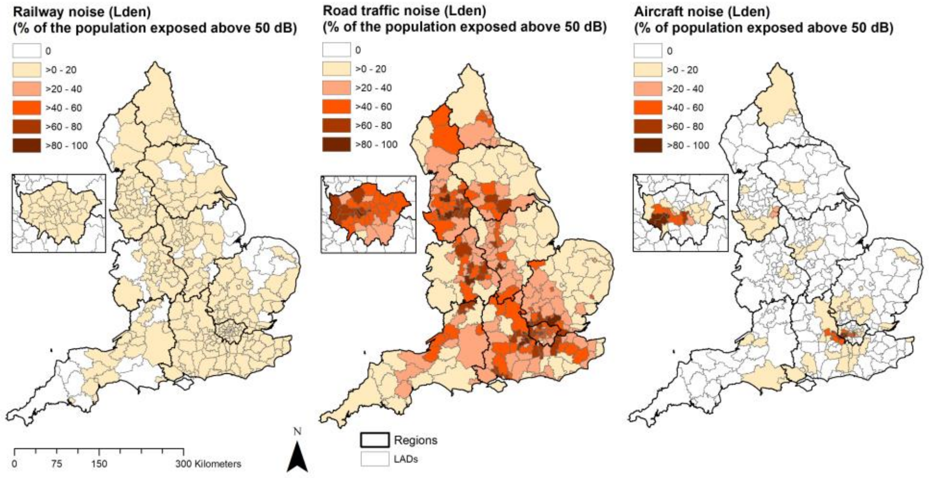
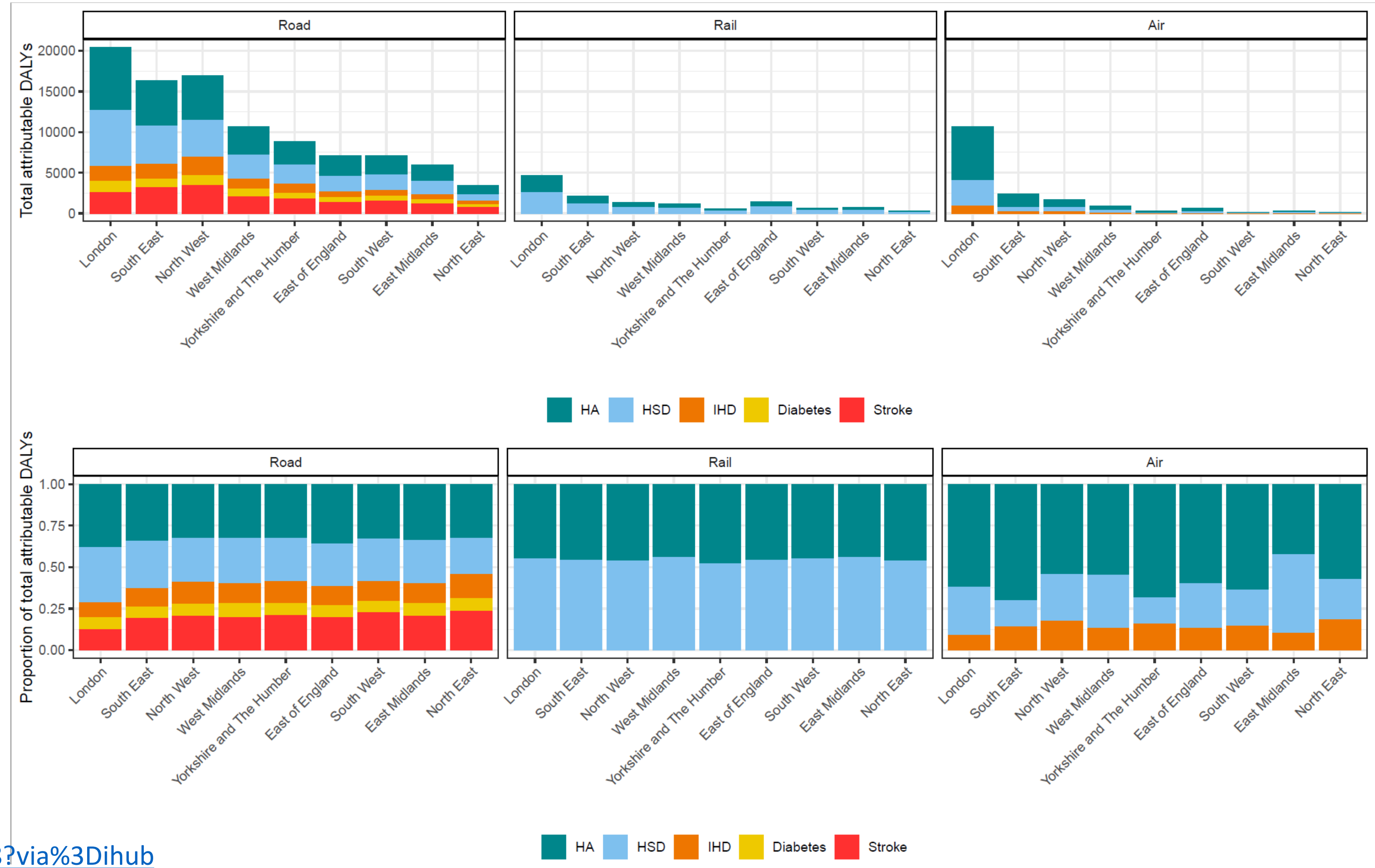
ABSTRACT

In the context of constructing a burden of disease (BOD) toolkit for noise exposures in England, we sought to identify meta-analyses to provide exposure-response coefficients that would update those available from the WHO Noise Guidelines for the European Region published in 2018. We conducted a systematic review of systematic reviews relating to noise exposure and selected health outcomes published in 2017-20. We used the AMSTAR checklist to score all selected systematic review papers at the same time as data extraction. A new review needed to have at least a moderate score on AM-STAR to be recommended as an alternative/update to the WHO analyses. Twenty-three papers were

https://www.ingentaconnect.com/contentone/ince/incecp/2023/00000265/00000002/art00044

Health risk assessments





https://www.sciencedirect.com/science/article/pii/S0160412023002398?via%3Dihub

What about other health outcomes?

Health outcome	Status	Health outcome / topic	Status
Annoyance – average, long term		Cognitive effects in children	
Annoyance – summer months		Cognitive decline in adults	
Annoyance – influence of NAFs		Mental health (depression, anxiety)	
Sleep disturbance – subjective		Wellbeing & Quality of Life	
Sleep disturbance – physiological		Reproductive outcomes	
Cardiovascular – IHD		Cancers	
Cardiovascular – hypertension		Population subgroups at higher risk	
Cardiovascular – stroke		Effectiveness of interventions	1
All-cause mortality		1. Reduced noise emissions	2
Metabolic – diabetes		2. sound insulation	3
Metabolic – obesity		3. respite 4. NAFs (compensation, communication, …)	4

NOTE: Colouring for demonstartion purposes only

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Slide prepared by B. Fenech for ANEG-Health meeting 05.06.2023

NAF – Non acoustic factors, IHD – ischaemic heart disease

Interventions

- Reducing noise exposure
  - Reducing noise emissions
  - Noise insulation
- Changing noise exposure
  - Distribution of flights temporally
  - Distribution of flights spatially (concentration vs multiple routes)
- Non-acoustic factors
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