Public Health England

Noise-related sleep disturbance

a brief overview of the scientific evidence

Dr Benjamin Fenech

Principal noise and health specialist

Environmental Hazards and Emergencies

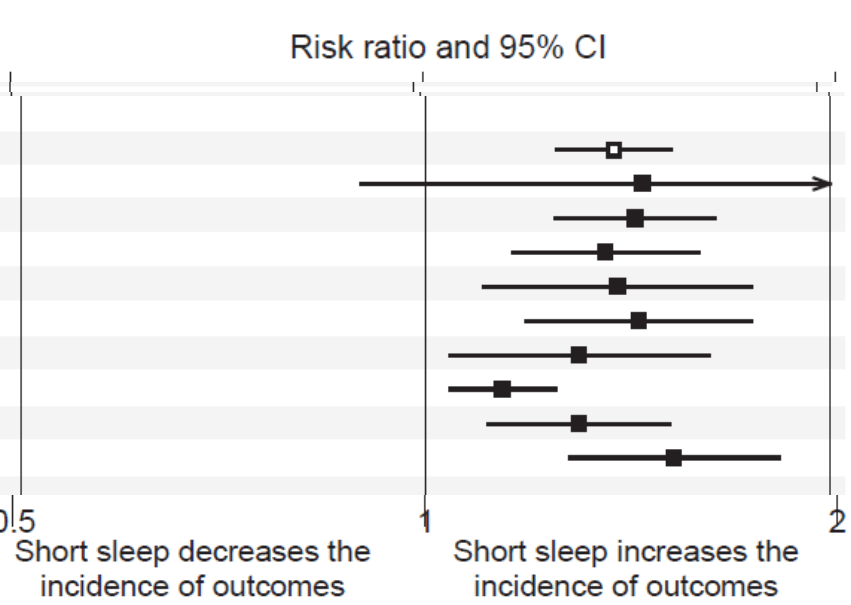
Centre for Radiation Chemical and Environmental Hazards

Public Health England

Public Health England

Sleep and health

	N of studies	Risk ratio	Lower limit	Upper limit
Obesity				
All	16	1.38	1.25	1.53
Aged 65 or over	1	1.45	0.89	2.36
Aged under 65	10	1.43	1.24	1.64
Female	8	1.36	1.16	1.60
Male	8	1.39	1.10	1.75
Sleep difined by night	6	1.44	1.18	1.75
High quality on the NOS	2	1.30	1.04	1.63
Follow-up no less than 10 years	2	1.14	1.04	1.25
Non borrowed prevalence rate	7	1.30	1.11	1.52
True outcome	9	1.53	1.28	1.83
Dyslipidemia				



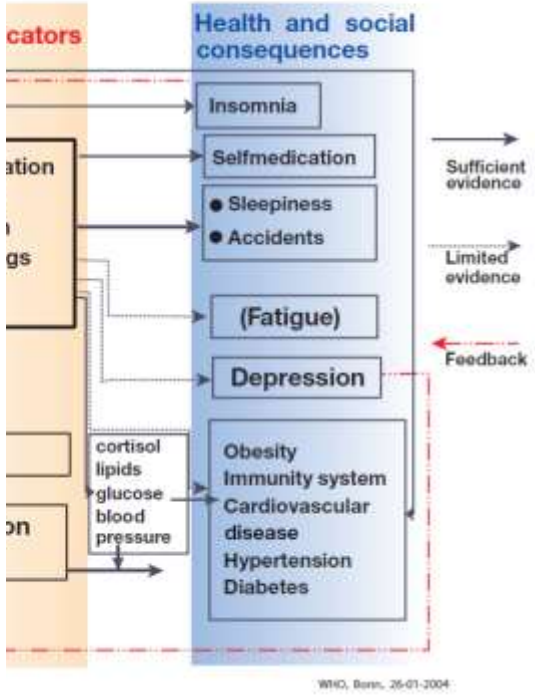
O. Itani et al. / Sleep Medicine 32 (2017) 246-256

Public Health England

Sleep and health

"The presence of feedback loops in the system is an indication that it may be ***difficult to prove direct cause–effect relations****. One example is the relation between sleep quality and depression. They are strongly associated, but it is uncertain if depression causes bad sleep, or bad sleep causes depression"*

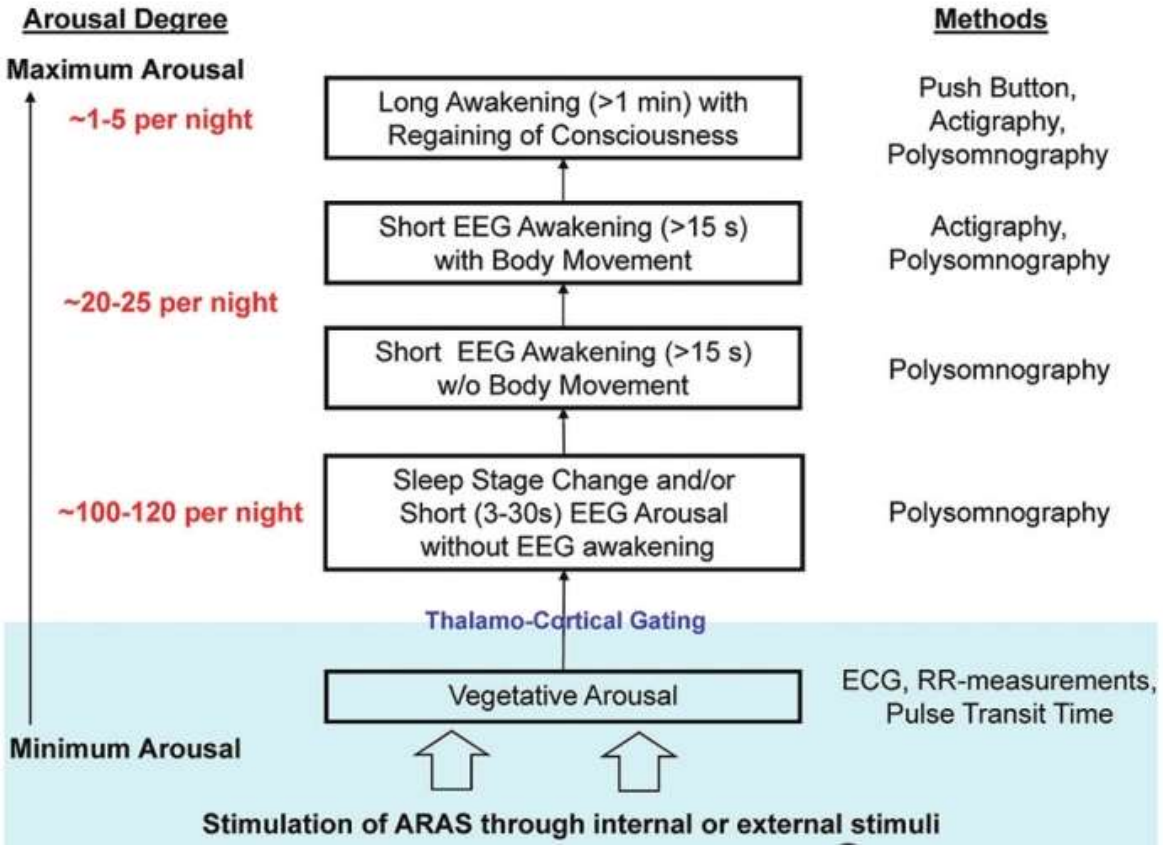
Fig.2.1
Expert view on the relations between sleep and health



WHO Regional Office for Europe 2009

Public Health England

Physiological reaction to external stimuli



Basner et al. / Noise Health 2012;14:321-9

Public Health England

Quantifying sleep disturbance

Methods	Positive-predictive value	Usability	Ease of analysis	Cost	Description	Definition of awakening
Polysomnography	High	Low	Low	High	Classifications of sleep stages by using data from an EEG, EOG and EMG	Number of sleep stage changes to wake from any other sleep stage[17] Or Any change from any sleep stages to the state awake or stage S1[18,20]
Seismosomnography[21]	Unknown	Low	Low	High	Measurement of small vibrancies of the body caused by a change of heartbeat, breathing and movement	Body movement (motility) as a proxy to awakenings
Actigraphy[26,29,30]	Low	Moderate	Moderate	Moderate	Detection of motor activity at the wrist	Movement as a proxy to awakenings
Questionnaire[31]	Low	High	High	Low	Subjects describe their sleep quality and number of recalled awakenings	
Push button	Low	High	High	Low	Subjects press a button when awakened; hence, defined as behavioural awakenings	

Perron et al./ Noise Health 2012;14:58-67

- Electrocardiography (Basner et al. Noise Health 2012;14:321-9)

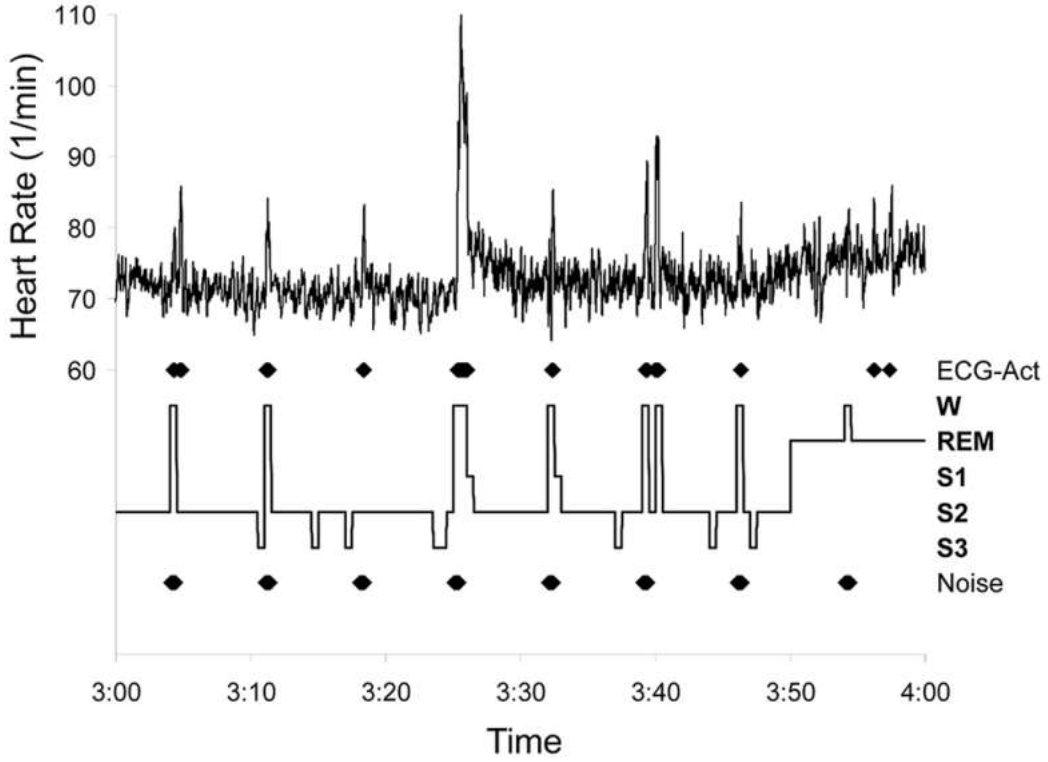
Public Health England

Physiological measures

Muzet / Sleep Medicine Reviews (2007) 11, 135–142

http://www.laermstudie.de/ergebnisse/ergebnisse-schlafstudie/neue-methode/

Basner et al. / Noise Health 2012;14:321-9



http://www.laermstudie.de/aktuelles/news/

Public Health England

Questionnaires

Sleep quality	Numerical		0–10	How would you rate your quality of sleep during the night? (very poor—very good)
			0–10	How do you normally sleep? (very poor—very good)
Exposure-related questions	Numerical disturbance from Exposure (E)		0–10	How disturbed was your sleep by vibration/noise from trains during the night? (not at all—extremely)
			2	Is your sleep disturbed by any noise? (yes, no)
	Verbal E causing poor sleep		1–5	Do you think that vibration/noise during the night disturbed your sleep so that you slept poorly? (not at all, hardly at all, fairly, very, extremely)
	Verbal E causing awakenings		1–5	Do you think that vibration/noise during the night disturbed your sleep so that you were awoken? (not at all, hardly at all, fairly, very, extremely)
	Verbal E causing difficulties to continue sleeping		1–5	Do you think that vibration/noise during the night disturbed your sleep so that you had difficulty falling asleep? (not at all, hardly at all, fairly, very, extremely)
	Verbal E causing tiredness in the morning		1–5	Do you think that vibration/noise during the night disturbed your sleep so that you felt tired in the morning? (not at all, hardly at all, fairly, very, extremely)
				rested, rather fresh and rested, rather tired, tired, very tired)
	Numerical tense		0–10	How are you feeling right now? (very relaxed—very tense)
	Verbal tense		1–5	How do you normally feel, when you wake up in the morning? (very at ease, rather at ease, neither at ease nor tense, tense, very tense)
	Numerical irritated		0–10	How are you feeling right now? (very glad, very irritated)

Croy et al./ Behavioral Sleep Medicine, 00:1–17, 2016

Public Health England

Questionnaires vs objective measurements

"Although most of the night is spent in an unconscious state, subjects were not only able to differentiate between nights with and without noise, but also between nights with low and high degrees of traffic noise exposure. Hence, if these findings extend to the field, morning questionnaires, although prone to manipulation, may be a very cost-effective way for the investigation of traffic noise effects on sleep."

Basner et al. / SLEEP, Vol. 34, No. 1, 2011

Croy et al../ Behavioral Sleep Medicine, 00:1–17, 2016

http://medicine.gu.se/english/phcm/occup_enviro/research/Sound_Environment_and_Health/the-sound-environment-laboratory

A. Skånberg, E. Öhrström / Journal of Sound and Vibration 290 (2006) 3–16

Pearsons et al../ J. Acoust. Soc. Am., Vol. 97, No.1 January 1995

Public Health England

Laboratory vs field studies

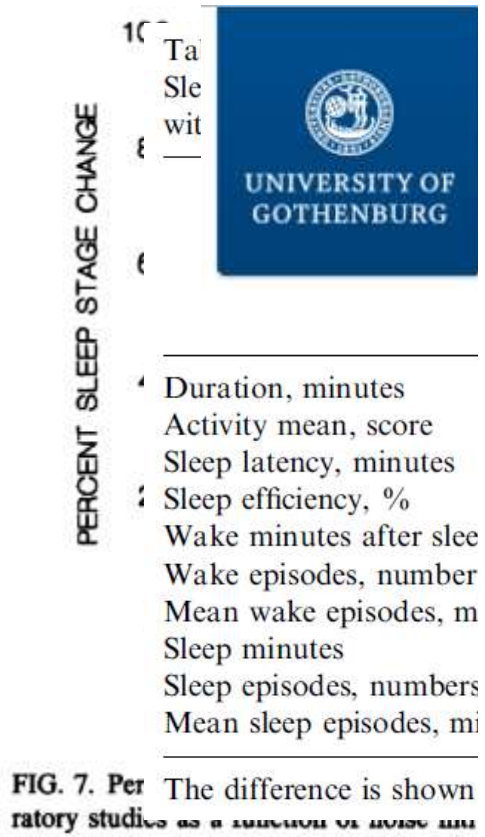


FIG. 7. Per … in field ratory studies as a function of noise lim

UNIVERSITY OF GOTHENBURG

Sound Environment and Health

News

The Sound Environment Laboratory

Research projects

Publications

The Sound Environment Laboratory

The new-built laboratory (finished 2006) is equipped with modern sound environment facilities and has very low background levels (LAeq 13 dB). This allows for studies of effects at low and moderate sound levels under well controlled conditions. The large exposure room with daylight can be used to simulate different environments (e.g., a courtyard, a living room) and three smaller rooms to simulate office settings or bedrooms. There is also a "home-like apartment" with separate entrance, a hall, two toilets (one with shower), a living room and a kitchen, in which the persons involved in different sleep studies can cook, watch TV or just relax.

Sound demonstration

The Sound Environment Laboratory is also used for audio demonstrations. For example, employees at the Swedish Transport Administration (Trafikverket) visited the lab and got to experience how 55 decibels of road traffic noise sounds like in different environments, or how vibrations from trains feels like when lying in a bed.

Leasing

It is possible to rent the Sound Environmental Laboratory. Please contact Kerstin Persson Waye for more information.
We are also open to collaboration in interesting research projects!

Public Health England

Habituation

Potential reason for cardiac arousal habituation **not** taking place **across** nights:

- hierarchal nature of arousal response

Demonstrates the potential relevance of cardiac arousals to long-term cardiovascular consequences of noise-induced sleep disturbance

Basner et al. / SLEEP, Vol. 34, No.1, 2011
Griefahn et al. / SLEEP, Vol. 31, No. 4, 2008

Public Health England

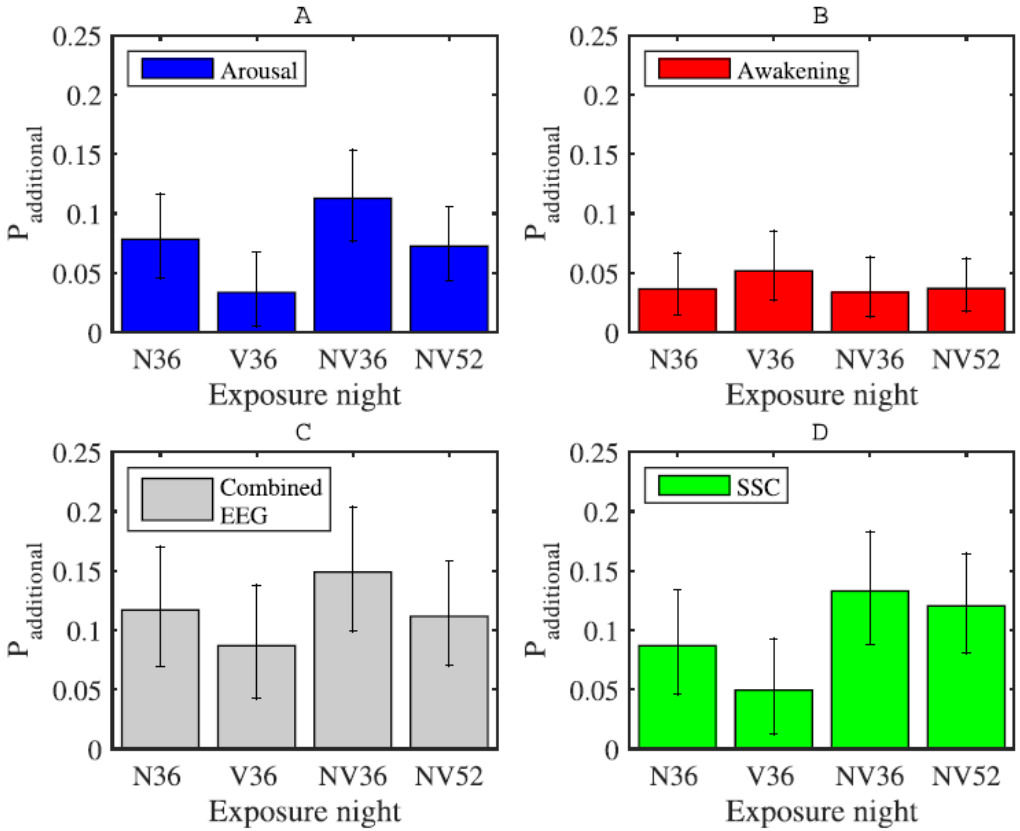
Modifiers / moderators

- acoustic factors (e.g. SPL, SPL above background, SPL rise time, duration of noise event), energy in high frequency ranges (≥ 4kHz), vibration)
- significance of noise for sleeper
- situational factors (e.g. elapsed sleep time, current sleep stage, …)
- personal factors (e.g. sex, age, noise sensitivity)
- inter-individual differences

McGuire et al../ SLEEP, Vol. 39, No. 5, 2016
Elmenhorst et al. / Science of the Total Environment 424 (2012) 48–56
Basner et al. / SLEEP, Vol. 34, No.1, 2011

Public Health England

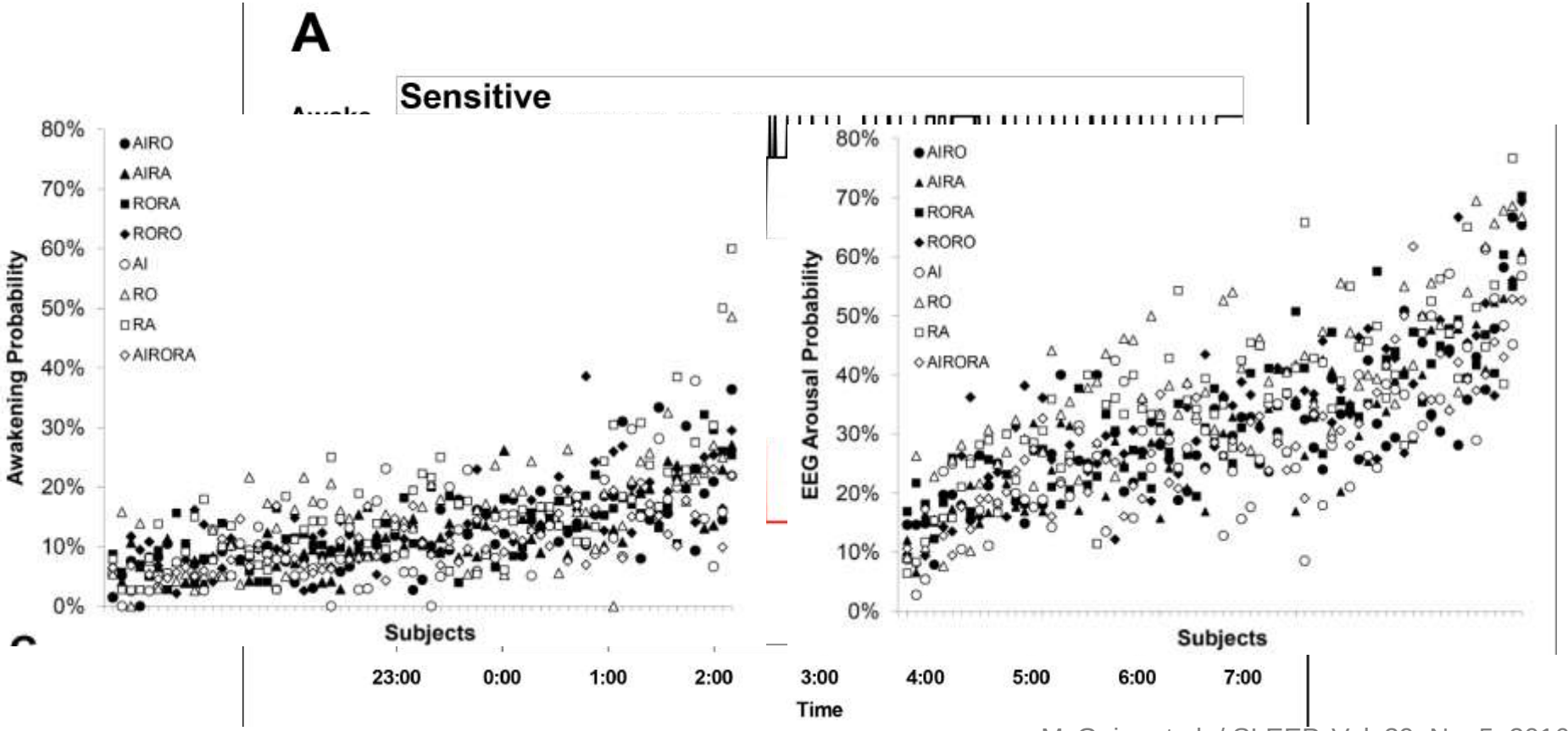
Influence of vibration



Smith et al../ J. Acoust. Soc. Am. 141 (5), May 2017

Public Health England

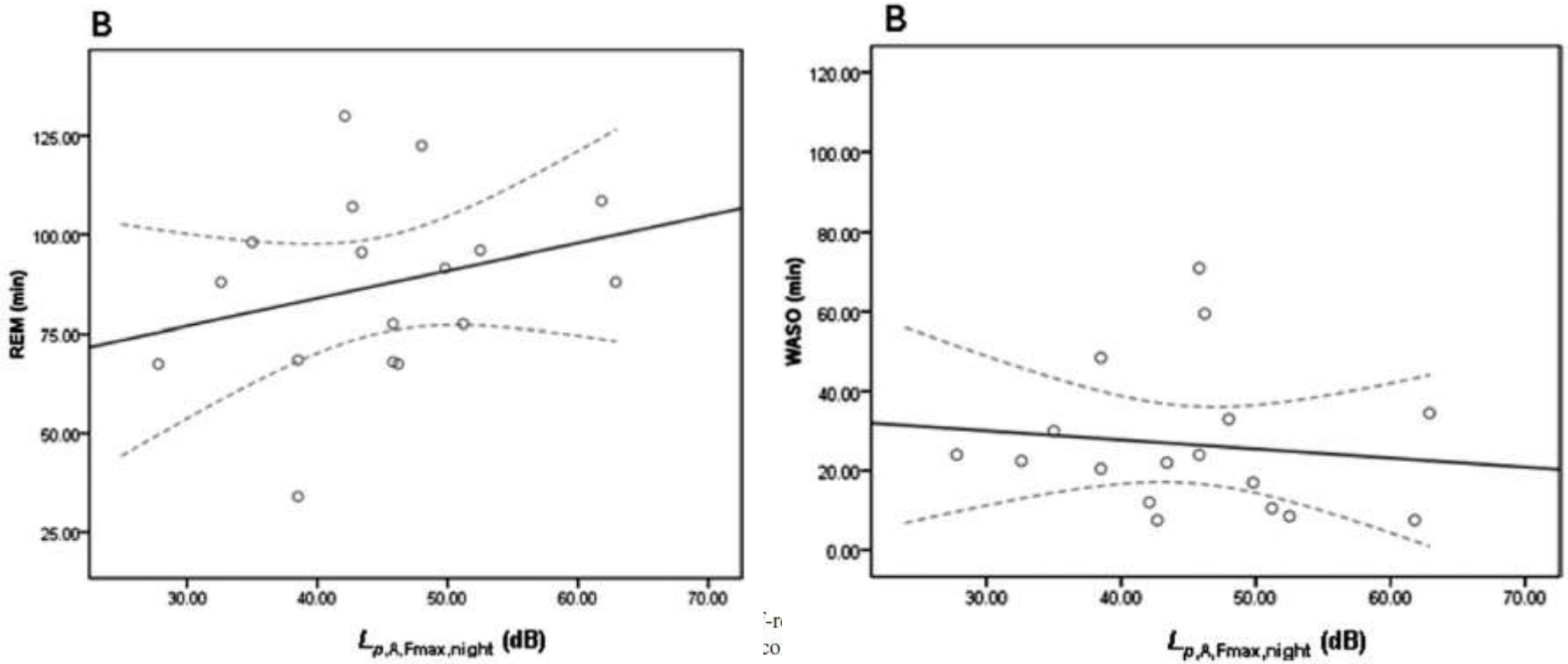
Inter-individual differences



McGuire et al../ SLEEP, Vol. 39, No. 5, 2016

Public Health England

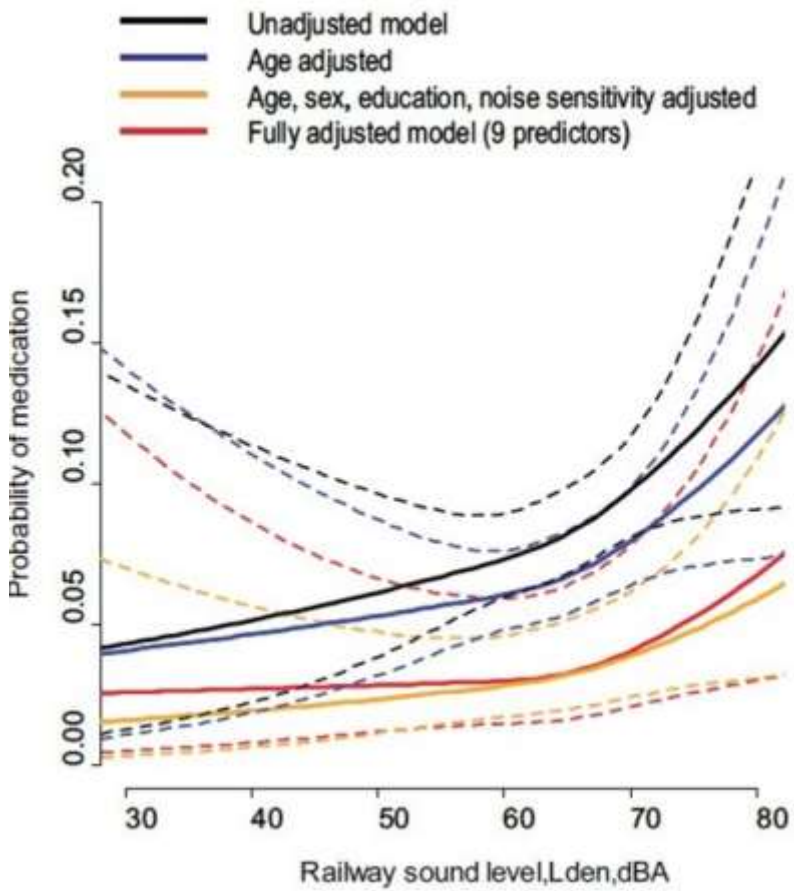
Road

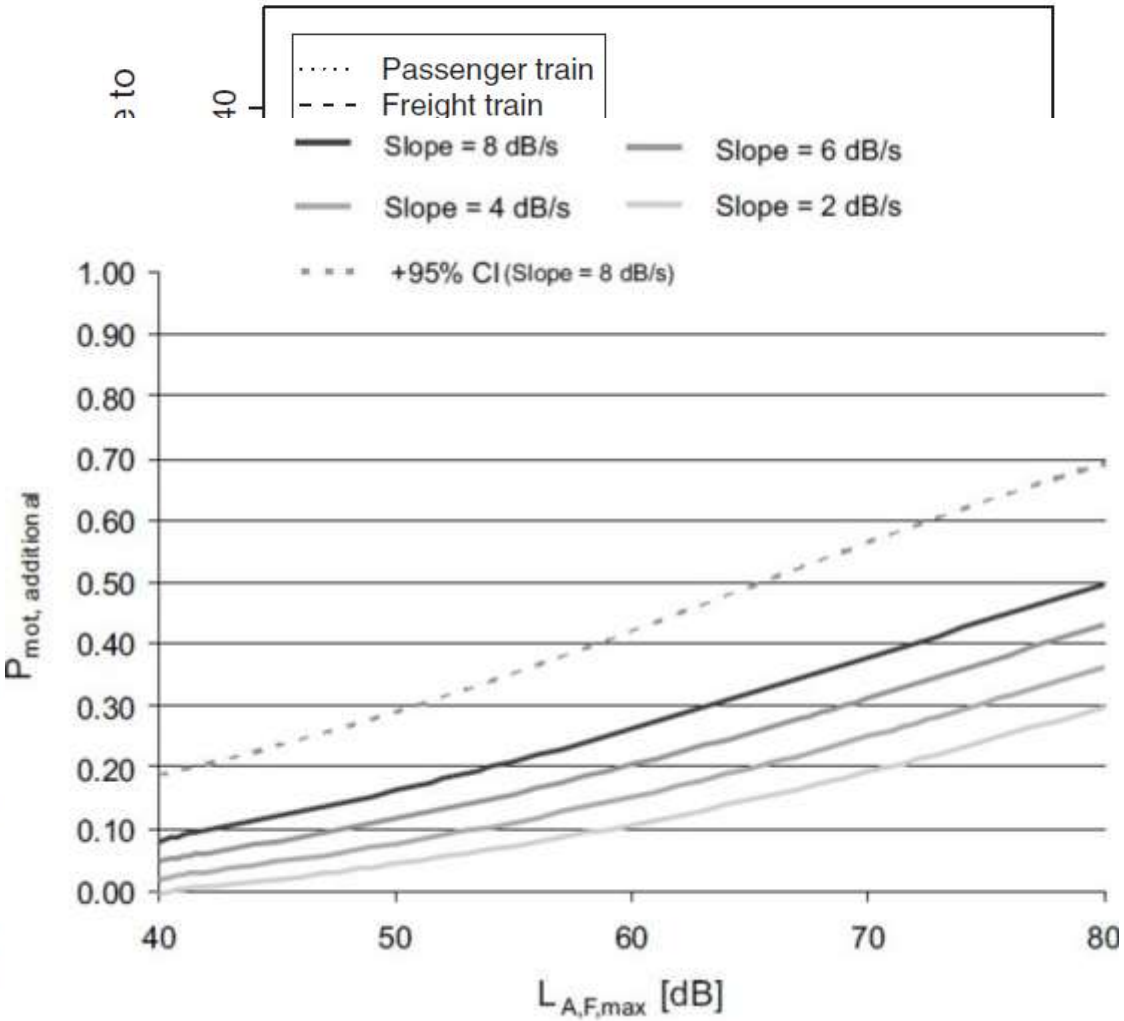


de Kluizenaar et al./ J. Acoust. Soc. Am., Vol. 126, No. 2, August 2009
Aasvang et al../ J. Acoust. Soc. Am., Vol. 129, No. 6, June 2011

Public Health England

Rail





second half of the night), elapsed
ent began = 11 epochs (median),
nd pressure rise time depending
= 34 years (median), gender =

Elmenhorst et al. / Science of the Total Environment 424 (2012) 48–56
Lercher.et al. / Noise Health 2010;12:110-9

Public Health England

Aircraft

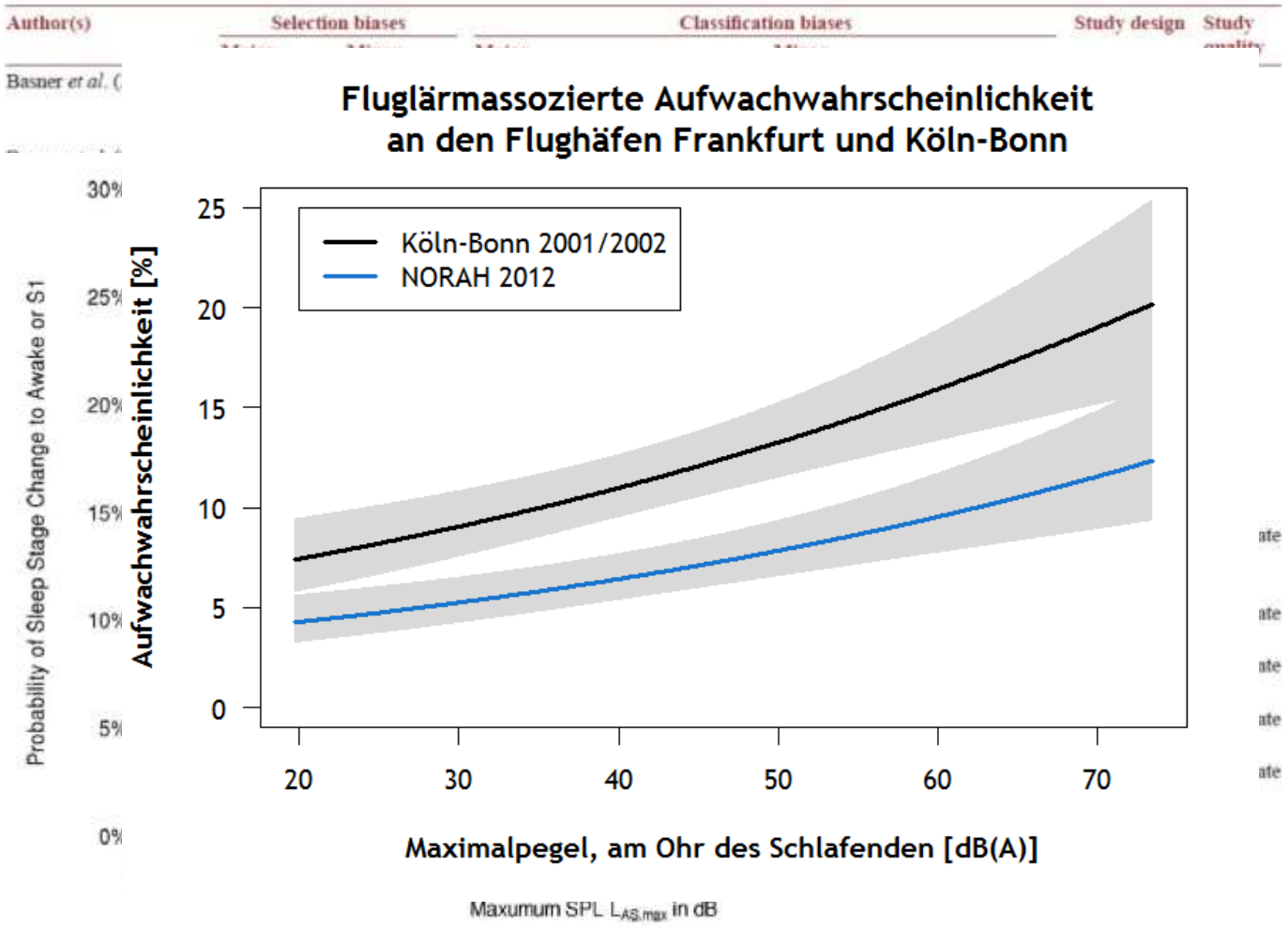


FIG. 1. Probability of sleep stage change to stage S1 or awake depending on maximum SPL $L_{AS,max}$ based on the regression results from Table I. Assumptions: Background noise level L_{eq}–1min=27.1 dB constant (median), prior sleep stage = stage 2, elapsed sleep time = 601 epochs (middle of second half of the night). Point estimates (black line), 95% confidence limits (gray lines), and spontaneous reaction probabilities (dashed line) are shown.

Perron et al./ Noise Health 2012;14:58-67
Basner et al. / J. Acoust. Soc. Am., Vol. 119, No. 5, May 2006
http://www.laermstudie.de/aktuelles/news/

Public Health England

Impact of interventions

road tunnel Göteborg city, Sweden

Fig. 1. Investigation area.

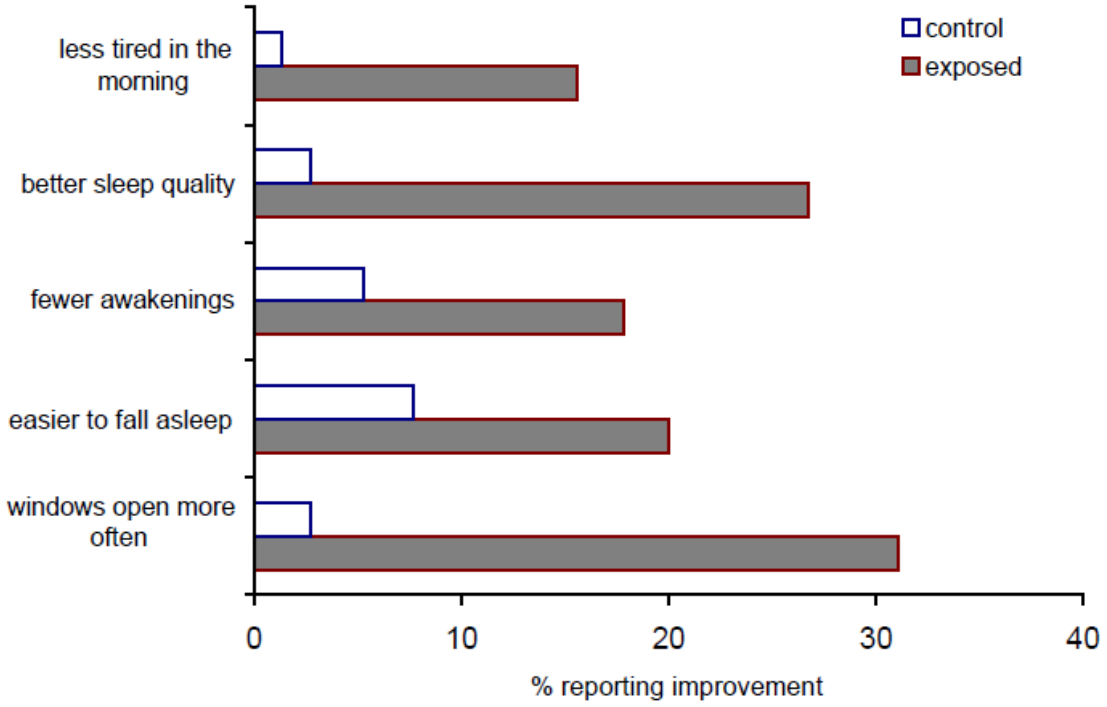


Fig. 2. Residents' own comparisons of sleep after the change in road traffic.

Public Health England

Impact of interventions

NOise-Related Annoyance, cognition, and Health (NORAH)

"The results of the sleep study show that with the initiation of the night flight ban […] the frequency of awakenings associated with aircraft noise decreased on average from 2.0 per night in 2011 to 0.8 per night in 2012. Thus, an important objective of the night flight ban has been reached."

"The subjective experience of sleep worsened statistically significantly from 2011 to 2013 by 5% and 11%, respectively, despite the introduction of the night flight ban, regardless of the aircraft noise exposure."

Müller / Internoise 2016

Public Health England

Opportunities & challenges

- we have good-quality evidence to underpin risk assessments and inform decision-making
  - but most studies to date carried out on healthy subjects
- we need more evidence on sleep disturbance in population groups at higher risk (children, elderly, shift workers, people with pre-existing chronic diseases or sleep disorders)
- we need a better understanding of the link between acute arousals/awakenings and long term health conditions to inform noise interventions