Environmental Noise, Silence, Acoustic Protection and Health

7es Assisses nationales de la qualite de l'environnement sonore

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Noise and Sound

- Noise is 'unwanted sound'
- Notion of subjectivity: 'annoyance'…
- '*Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity*.' (Constitution of WHO, April 7, 1948)
- **BUT: is noise an objective threat to our health, regardless of subjective perception (i.e. being 'annoyed', sleep disturbed, …)?**

Noise: a problem of all times…

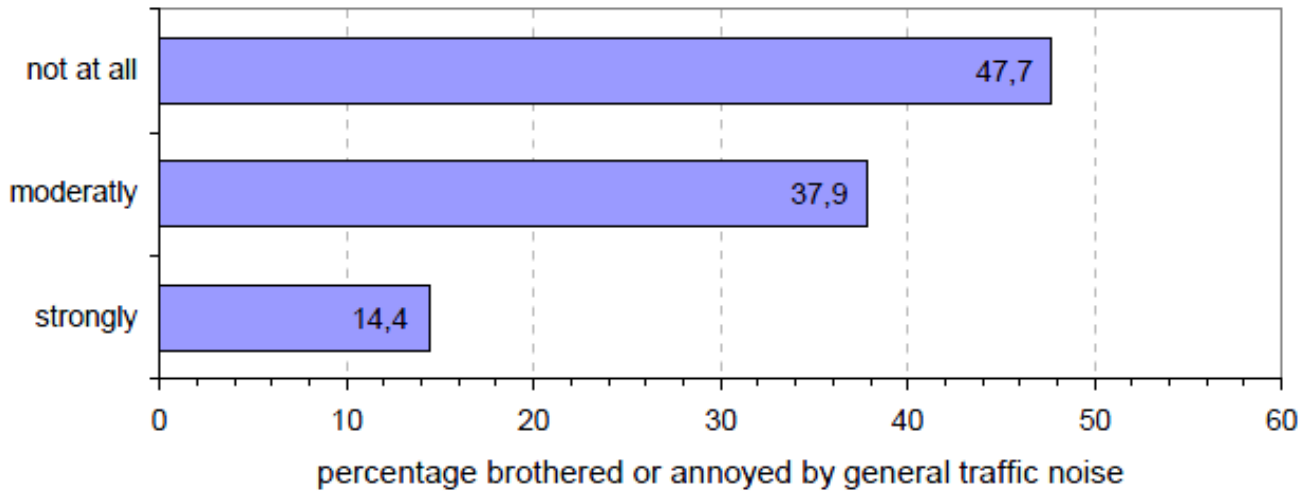
- *'… In ancient Rome, rules existed as to the noise emitted from the ironed wheels of wagons which battered the stones on the pavement, causing disruption of sleep and annoyance to the Romans.. '*
- *'… an immense number of cars regularly cross our cities and the countryside. There are heavily laden lorries with diesel engines…/… Aircraft and trains add to the environmental noise scenario (inferno?)…'*

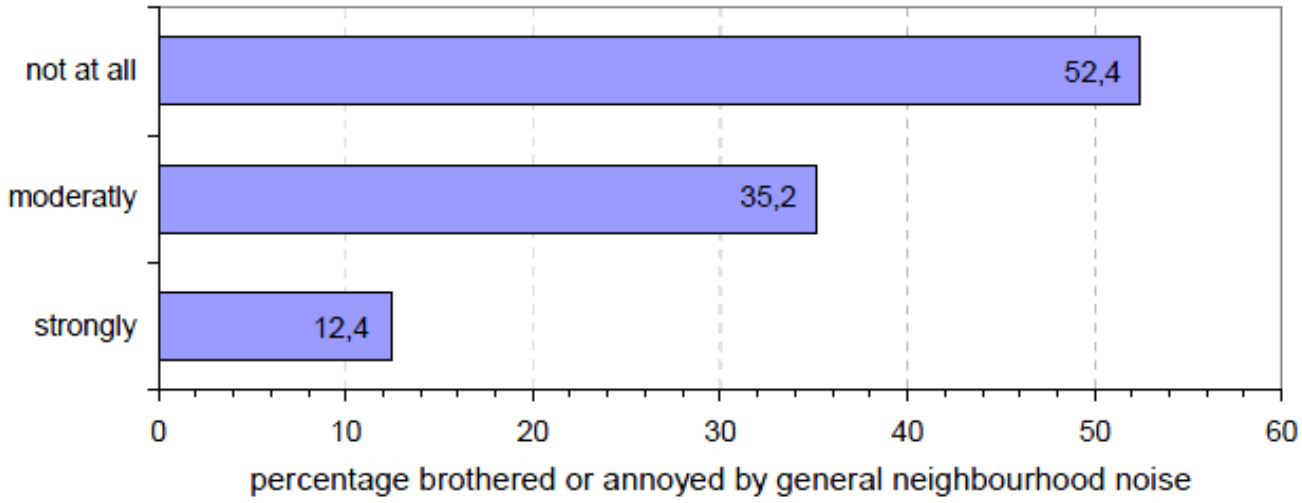
WHO Guidelines for Community Noise 1999

Environmental Noise (community noise)

- Noise emitted from all sources except noise at the industrial workplace
- Traffic (road, rail and air), industries, construction and public work,
- Indoor sources: **ventilation**, office machines, home appliances, …
- Neighbourhood: live or recorded music, sport events, dogs, children (kindergarten or day care centre, 'crèche'), playgrounds…
- Auditory versus extra-auditory effects of noise

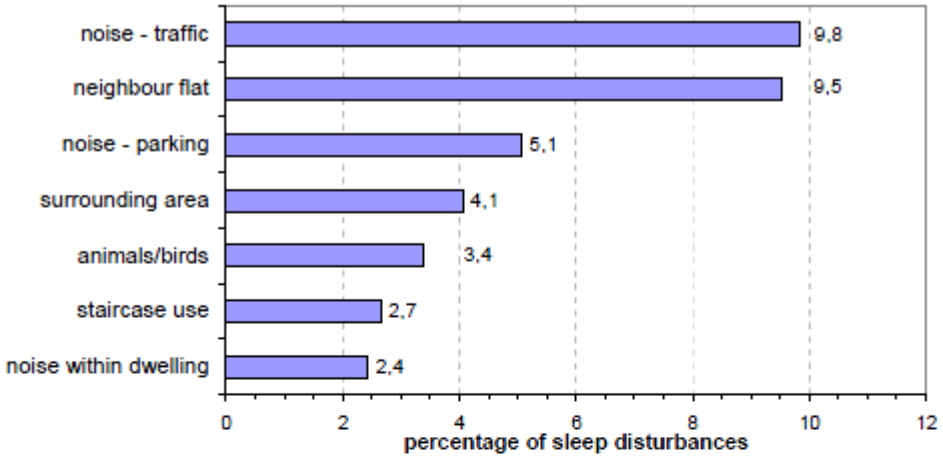
Noise annoyance: neighbourhood and traffic noise in competition (city)





WHO LARES 2004

Sources of sleep disturbance by environmental noise



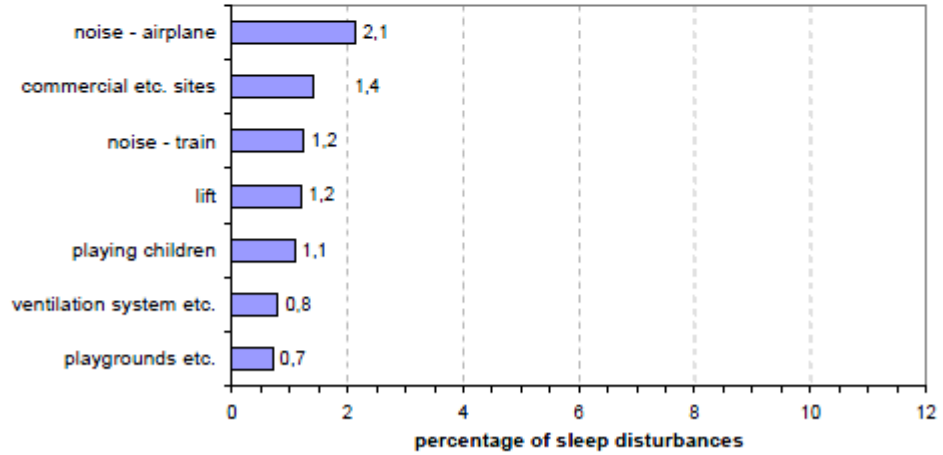


Figure 12: Percentage frequency of noise sources which induced sleep disturbances N = 8519 (adults, children and elderly)

WHO LARES 2004

Sleep disturbance by noise

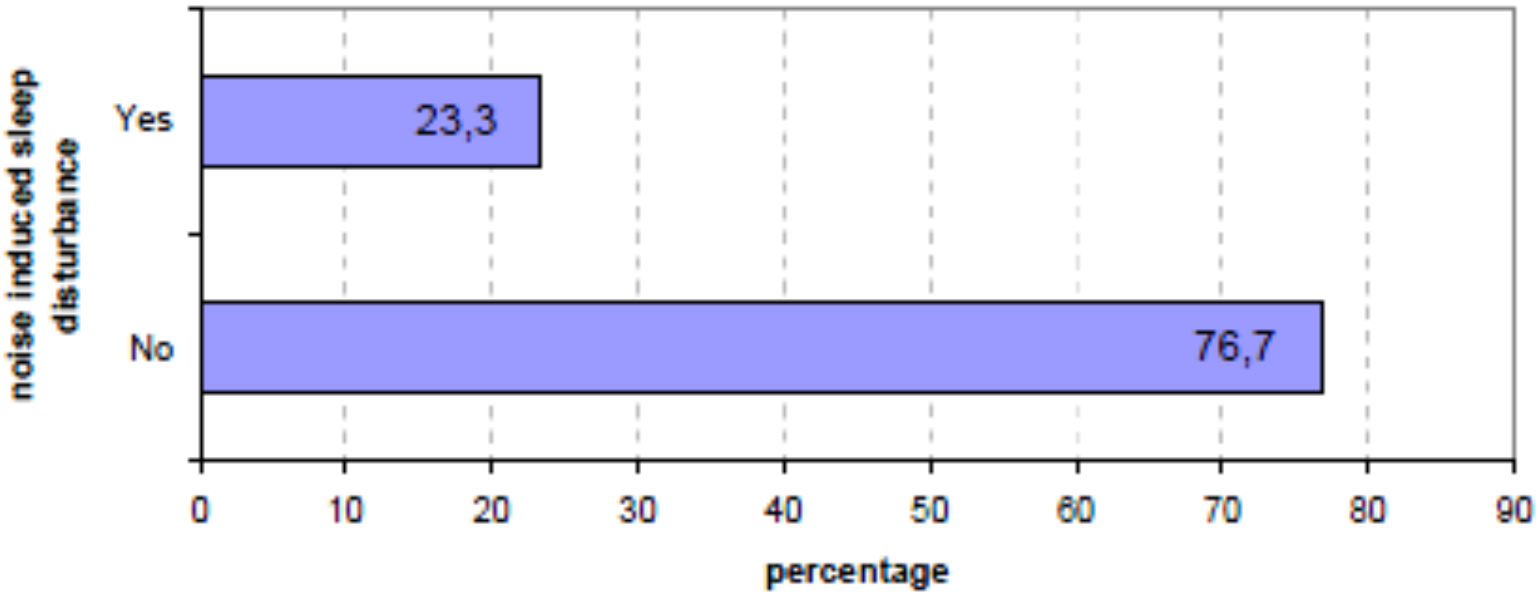


Figure 13: Percentage distribution of noise induced sleep disturbances in the whole sample (N = 8325)

WHO LARES 2004

Why are we so vulnerable to noise?

- **Awareness** of noise does not require attention (< > vision)
- The concept of the human ear as a ***24 hour around the clock ALARM SYSTEM*** : being aware (hearing) of 'environmental noise' was (and still is!) essential for survival of the human being (also during sleep; 'human ear never sleeps')>> **NOISE = DANGER**
- Hearing occurs in **three steps**:
  - Sound impulses strike the inner ear and are processed and transmitted via the auditory nerve to the central nervous system (CNS)
  - Analysis by the CNS
  - Appropriate reaction
    - At the autonomous (uncounscious) level: **ALWAYS** (**no habituation)**
    - At the conscious level: **SOMETIMES** (habituation can occur but **what is habituation to noise?)**
- **Importance of sleep for health**

Scheuch K et al. Reviews on Environmental Health 2003;18:185

The human body reacts autonomously to noise day and night

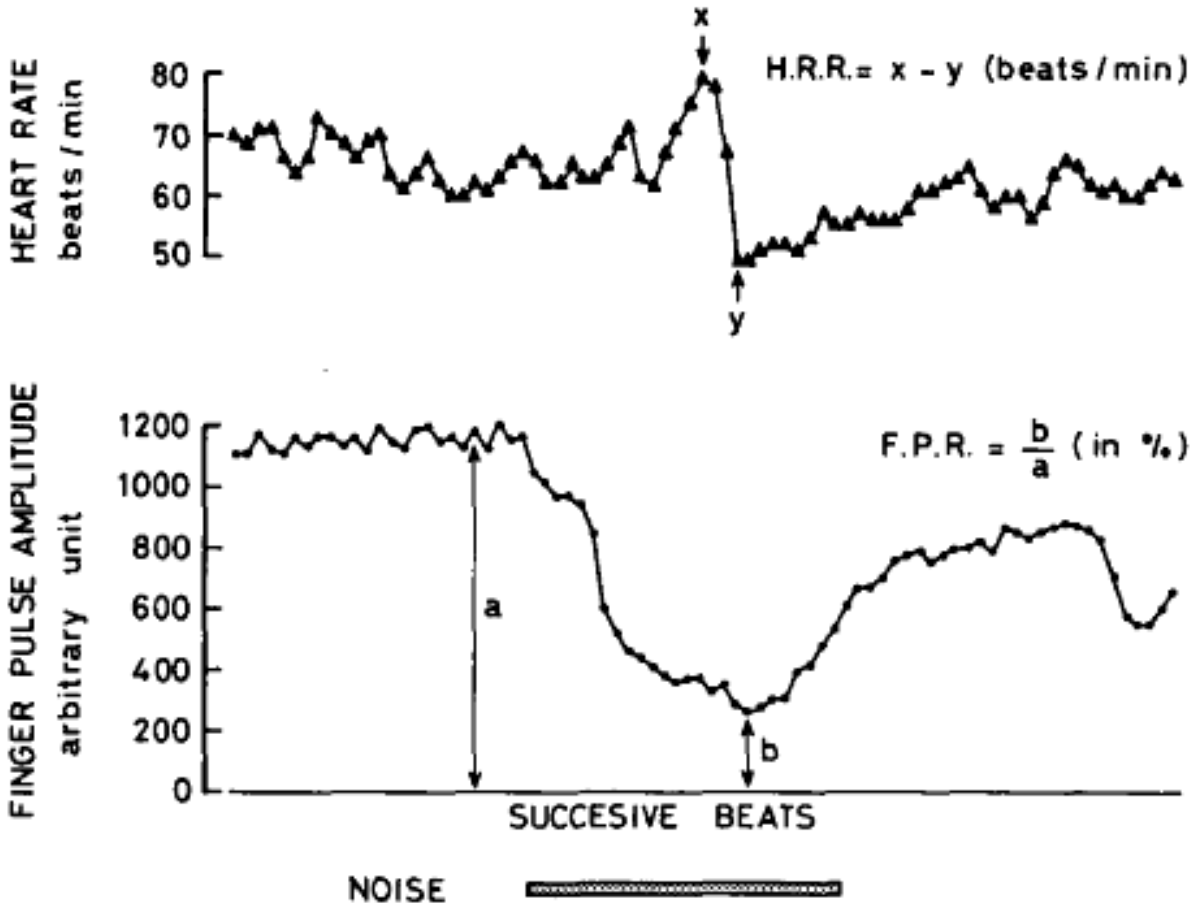


FIG. 3. Examples of heart-rate response (HRR) and finger pulse response (FPR) induced by noise.

Di Nisi et al. Comparison of cardiovascular responses to noise during waking and slieeping in humans SLEEP 1990:13:108

Cardiovascular response to noise
Comparison Day/Night (- 15 dB)

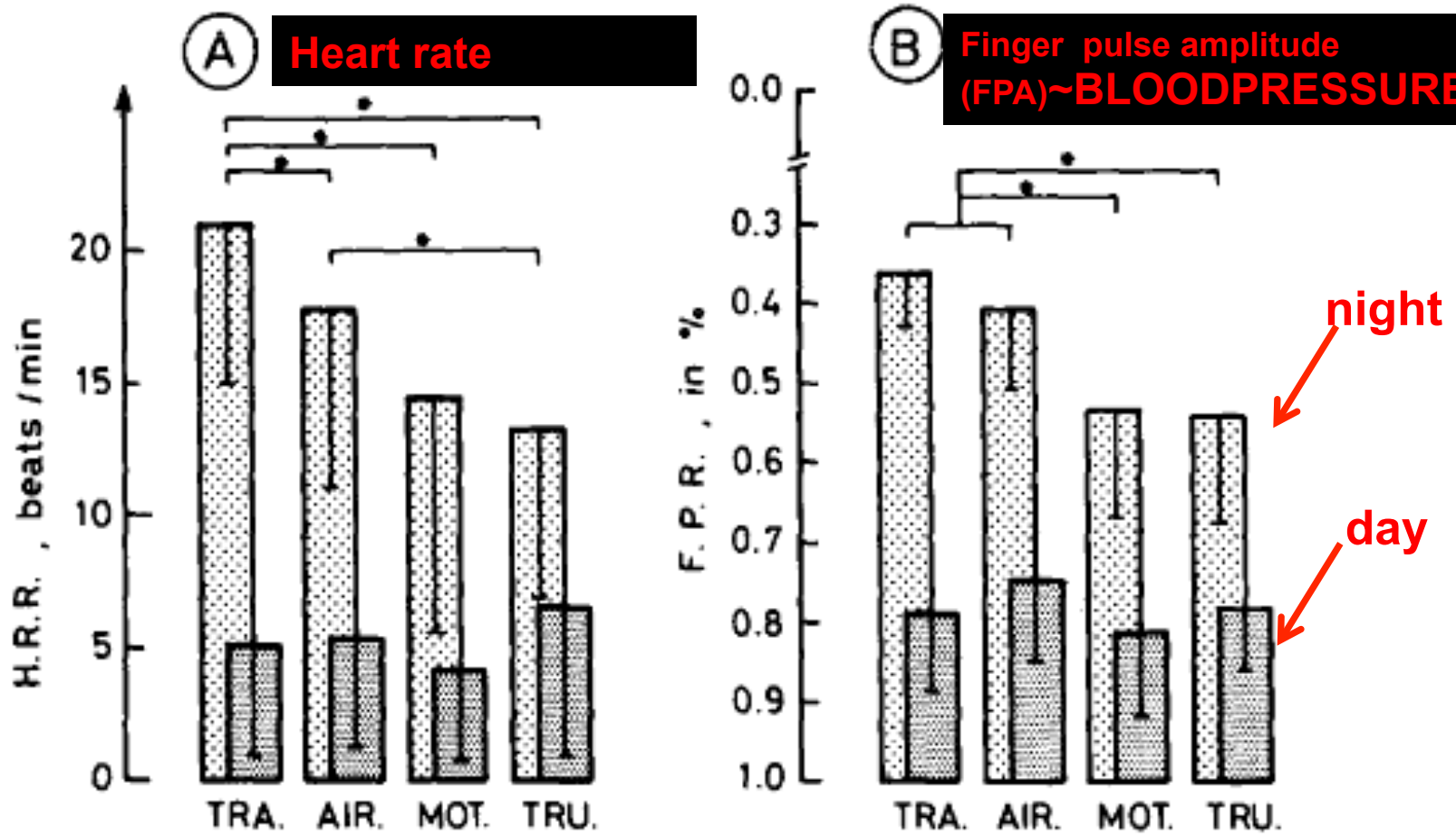
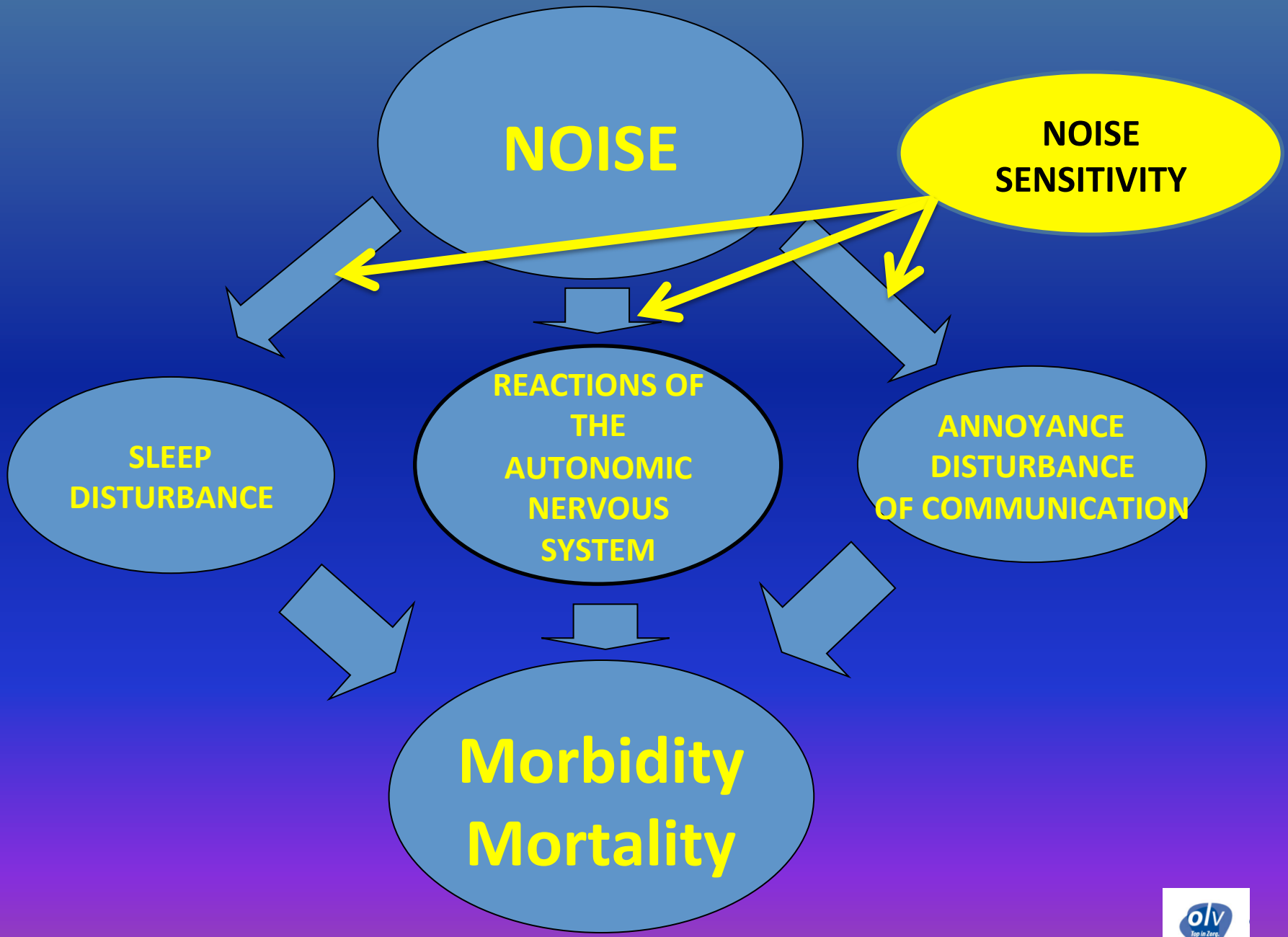


FIG. 5. HRR (A) and FPR (B) obtained for the 20 subjects during sleep and in the awake state. Between-noise comparisons are given for the nocturnal values (mean ± standard deviation). Asterisk = $p \leq 0.008$. ⬚, nocturnal results; ▨, daytime results.

Di Nisi et al. Comparison of cardiovascular responses to noise during waking and sleeping in humans SLEEP 1990:13:108


NOISE
NOISE SENSITIVITY
SLEEP DISTURBANCE
REACTIONS OF THE AUTONOMIC NERVOUS SYSTEM
ANNOYANCE DISTURBANCE OF COMMUNICATION
Morbidity Mortality

Why is sleep so important to our health?

- **Restoration:** during sleep there is intense anabolic activity (e.g. peaking of growth hormone during SWS (deepest fase of sleep, mostly in first half of the night**)**
- Some functions of the brain are attributed exclusively to sleep (e.g**. consolidation of memory and brain plasticity)**
- **Immunology**: a good sleep amplifies the immune response (role in infection risk, cancer, …)
- A good sleep is essential for **sugar metabolism and blood pressure regulation** and protects against related disorders (diabetes, obesity, hypertension, metabolic syndrome,…)
- …

Sleeping anesthesiologists…

Table 2. Time spent by sleep-deprived anesthesiology residents in sleepy behaviors during a 4-hour simulated laparoscopic operation*

Subject	Minutes (% time of entire operation)
4	77.7 (32.4%)
12	60.2 (25.1%)
6	26.7 (11.1%)
9	12.5 (5.2%)
7	11.4 (4.8%)
5	6.6 (2.8%)
3	3.1 (1.3%)
11	2.1 (0.9%)
2	0
8	0
10	0

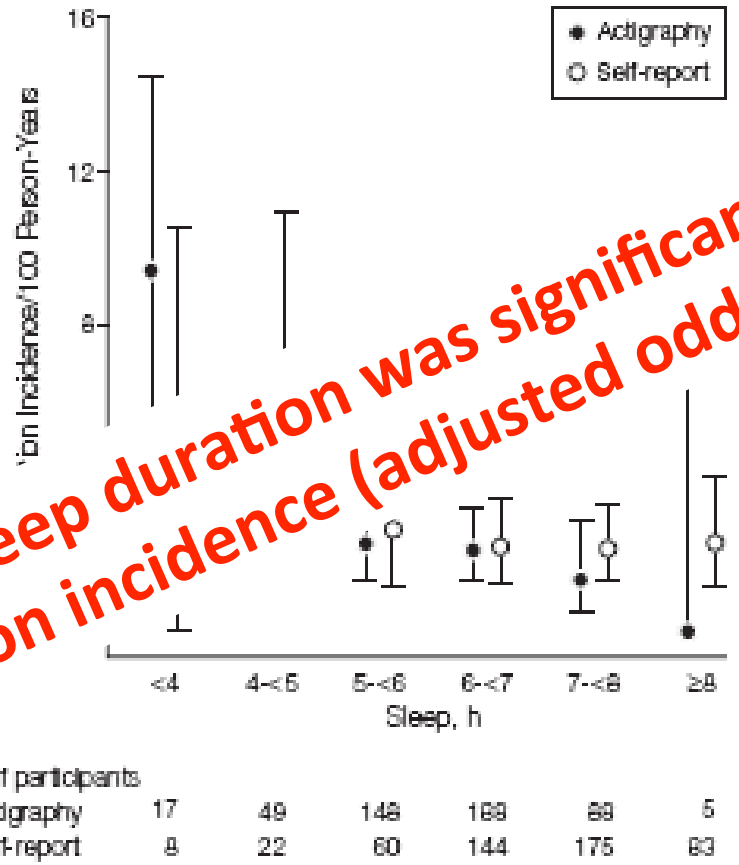
*"Sleepy behaviors" are defined as nodding and eyes closing (awakened head bob); nodding and eyes closing (not awakened); or eyes closed with no movement (sound asleep). Data from reference 6.

Howard S BUMC PROCEEDINGS 2005;18:108–112

Restorative function of sleep

- *'Just as when people don't eat they become hungry and when they don't drink they become thirsty, when they don't sleep they become sleepy*' (Steven Howard *BUMC PROCEEDINGS* 2005;18:108–112)
- Short sleep duration (lack of sleep) and/or diminished sleep quality begets **premature ageing**
- **Total sleep deprivation provokes death** (in rats after 18 days vs 17 days with starvation)
- **Children sleep longer than adults** (at 3 years 10.5 hours exclusive of naps during daytime!)

Sleep duration and incidence of coronary artery calcification (CARDIA)



Error bars indicate 95% confidence intervals, which are 95% binomial intervals. Three self-reports were missing. $P<.001$ for trend for actigraphy and $P=.12$ for trend for self-report.

Longer measured sleep duration was significantly associated with reduced calcification incidence (adjusted odds ratio, 0.67 per hou

King R et al. JAMA 2008;300: 2859-2865

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- …

Antibody response after hepatitis A vaccination

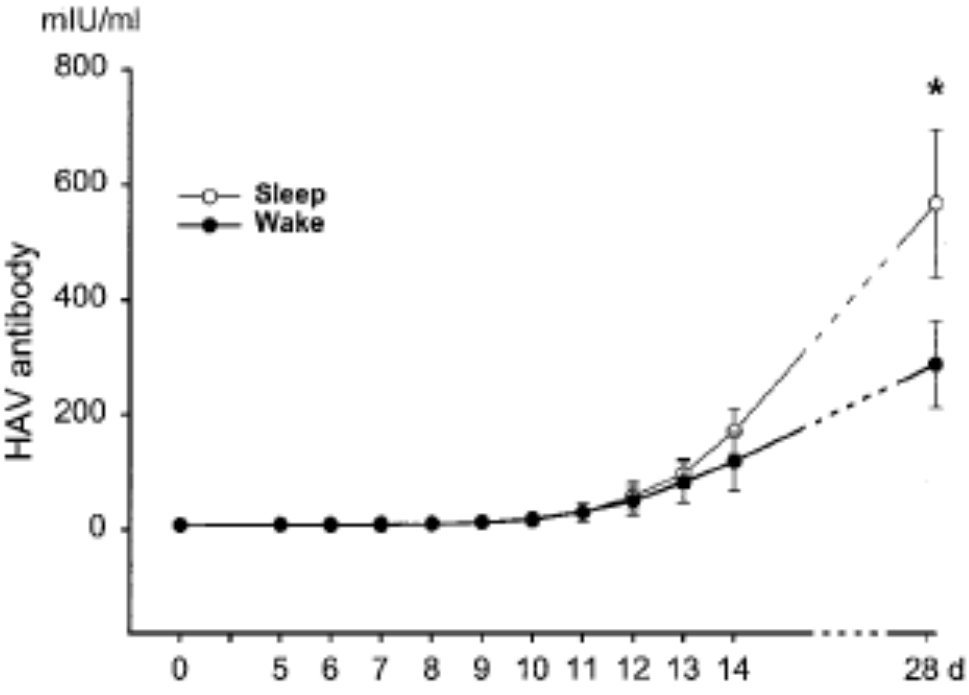

Fig. 1. HAV antibody titers. Mean (± SEM) anti-HAV titer in mIU/ml before (day 0) and after (days 5–14 and day 28) hepatitis A vaccination in subjects who had either regular sleep on the night after vaccination (thin line, open circles) or were kept awake on this night (thick line, filled circles). *p = .018, for comparison between the effects of sleep and the wakefulness on day 28.

Lange T et al Psychosom Med 2003 Sep-Oct;65(5):831-5.

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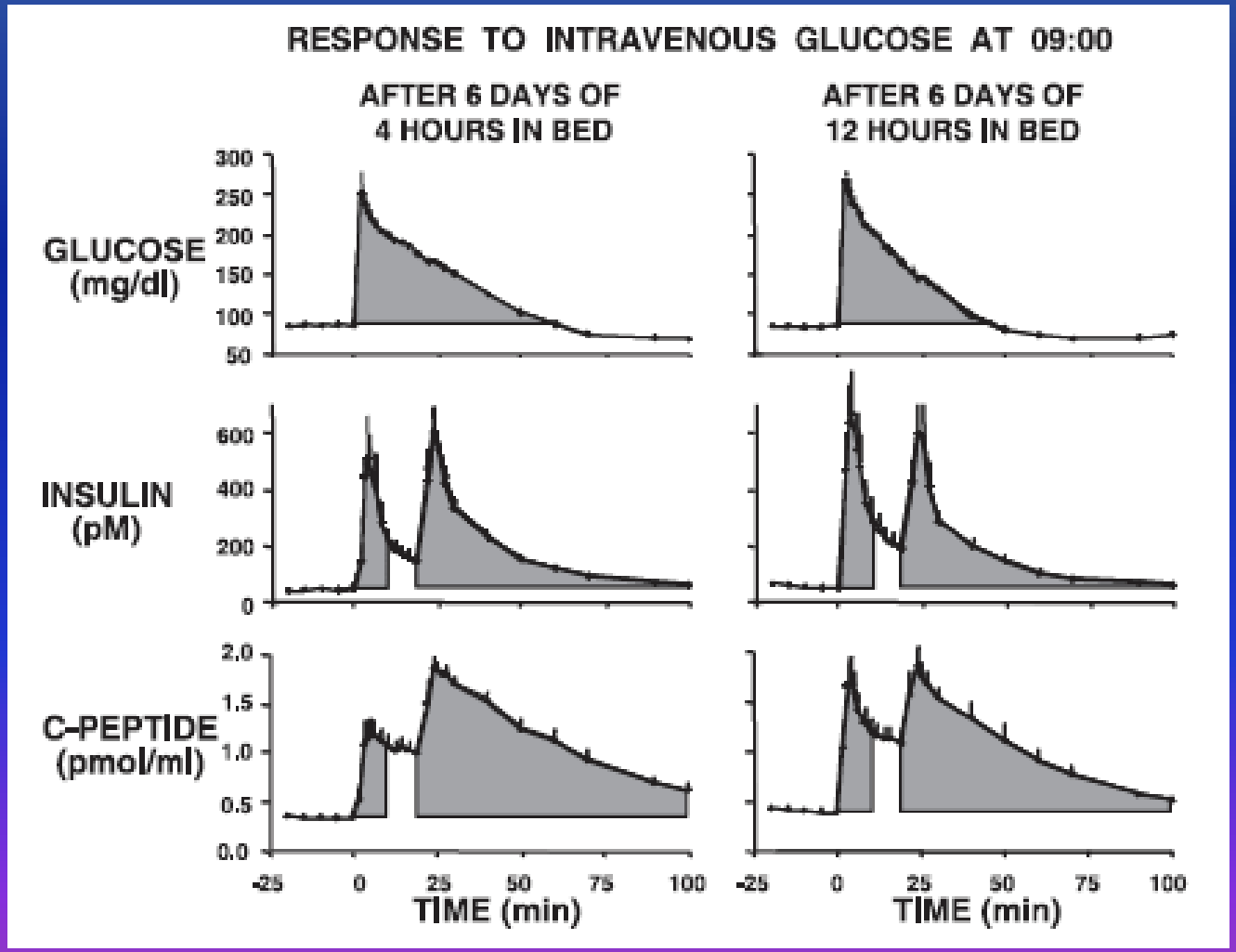
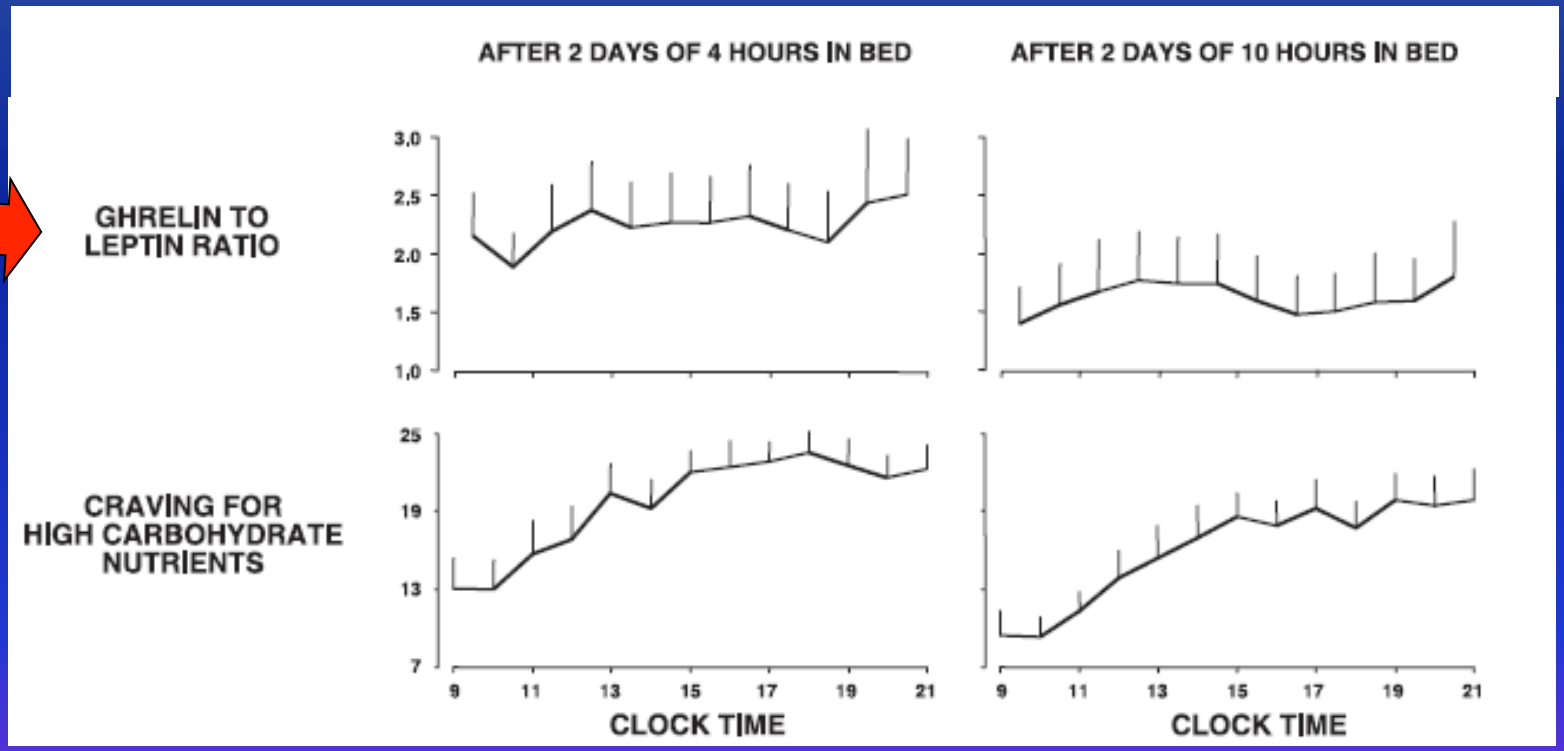
- **…**

Short sleep has a harmful impact on glucose metabolism



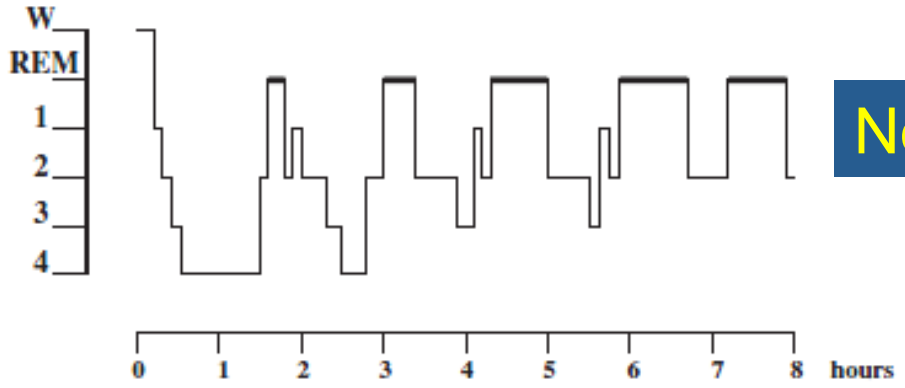
Spiegel et al J Appl Physiol 2005

Sleepdebt stimulates appetite

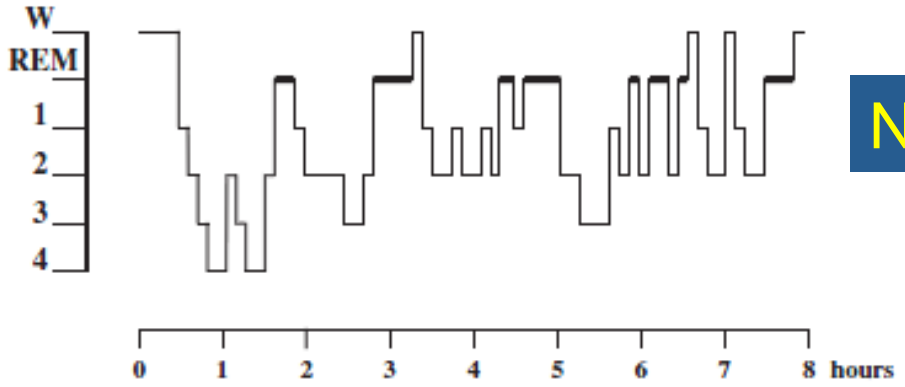


Spiegel et al J Appl Physiol 2005

Sleep disturbance by noise (polysomnogram)



Normal night

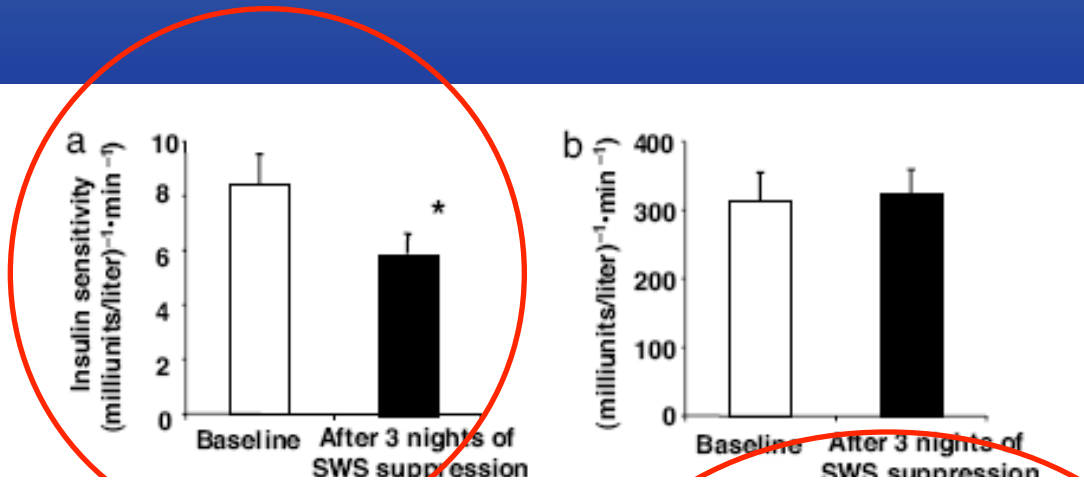


Noisy night

Muzet A. Environmental Noise, Sleep and Health Sleep Medicine Reviews 2007:11:135

Slow-wave sleep and the risk of type 2 diabetes in humans

Esra Tasali*, Rachel Leproult, David A. Ehrmann, and Eve Van Cauter



The metabolic impact of the change in S.I. was comparable with that associated with a weight gain of 8–13 kg

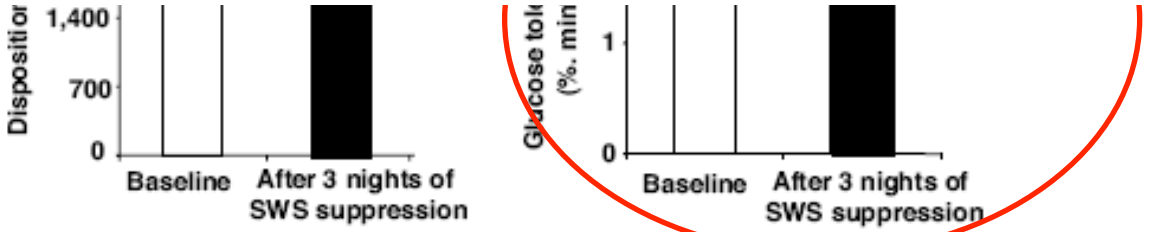
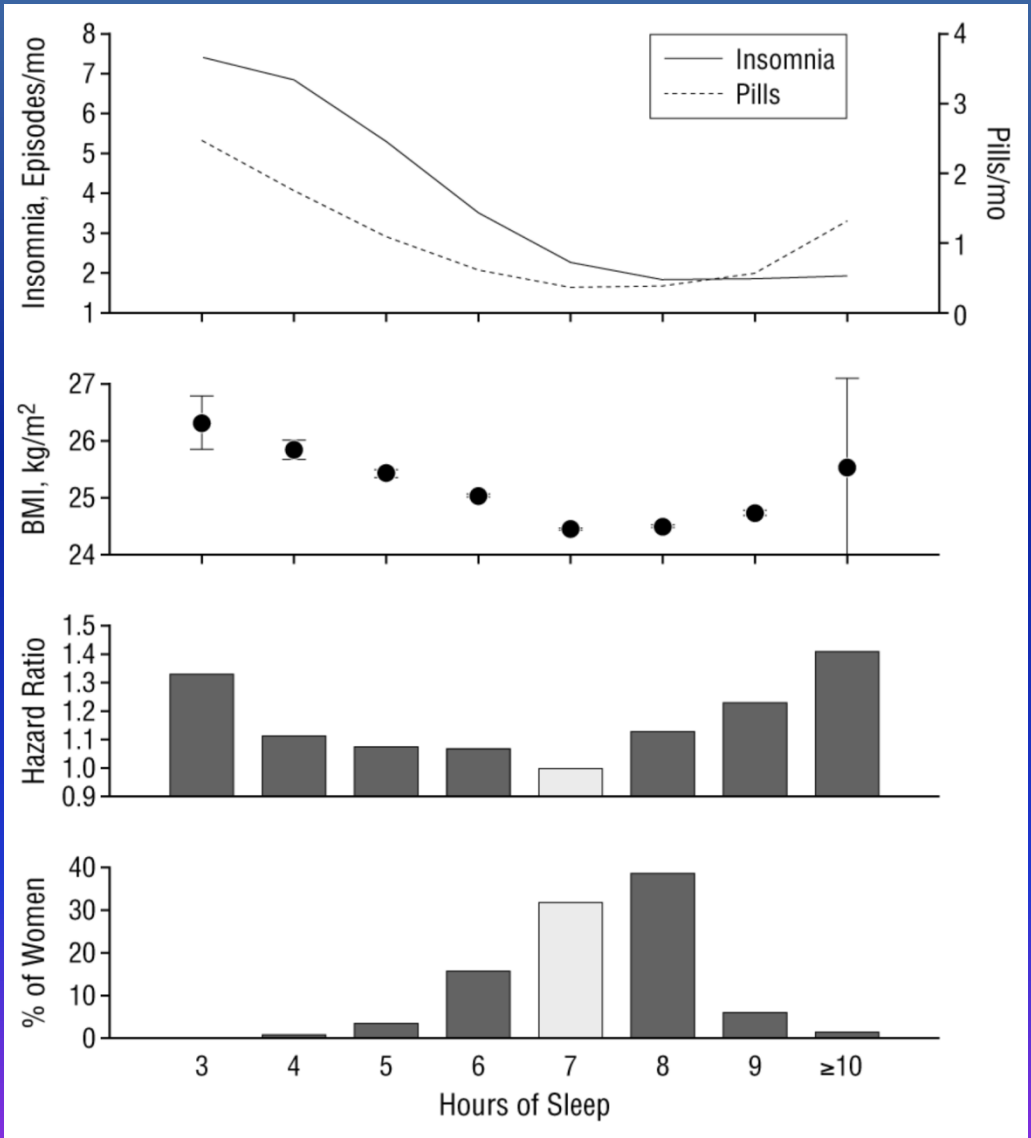


Fig. 1. S.I., AIRg, DI, and glucose tolerance at baseline and after 3 nights of SWS suppression. The data are means ± SEM (n = 9 subjects). The asterisks indicate significant differences (paired t test): S.I. (P = 0.009) (*a*); AIRg (P = 0.73) (*b*); DI (P = 0.02) (*c*); and glucose tolerance (P = 0.03) (*d*).

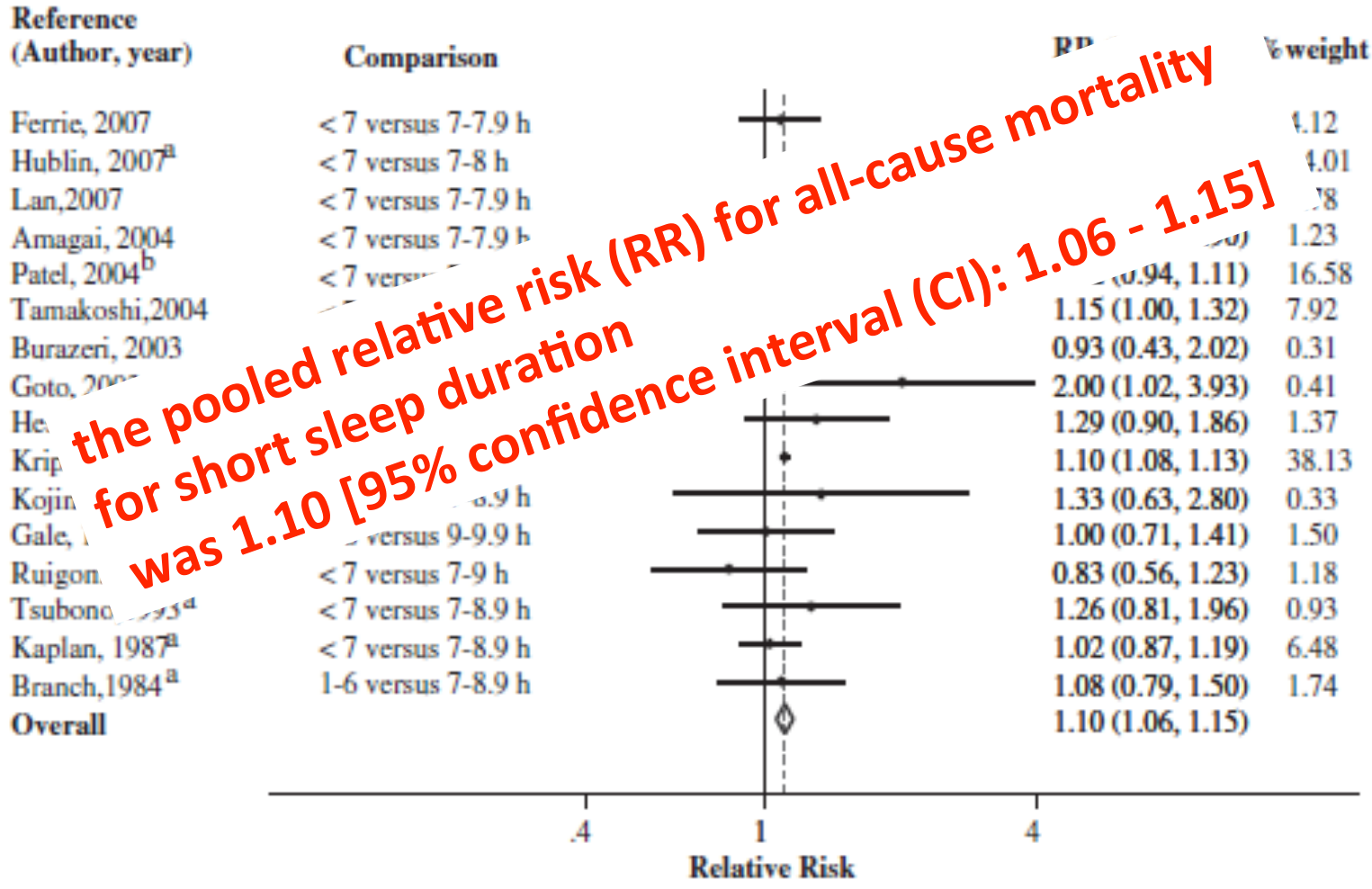
: Mortality Associated With Sleep Duration and Insomnia



Arch Gen Psychiatry. 2002;59(2):131-136.

For 636 095 women, the average reported frequency of insomnia, the average number of sleeping pills used per month, and the mean body mass index (BMI) according to reported hours of sleep. The 95% confidence intervals of the BMI are shown. Also shown are the hazard ratios from the 32-covariate Cox models and the percentage of women reporting each sleep duration. The reference duration of 7 hours is represented by the lighter bars.

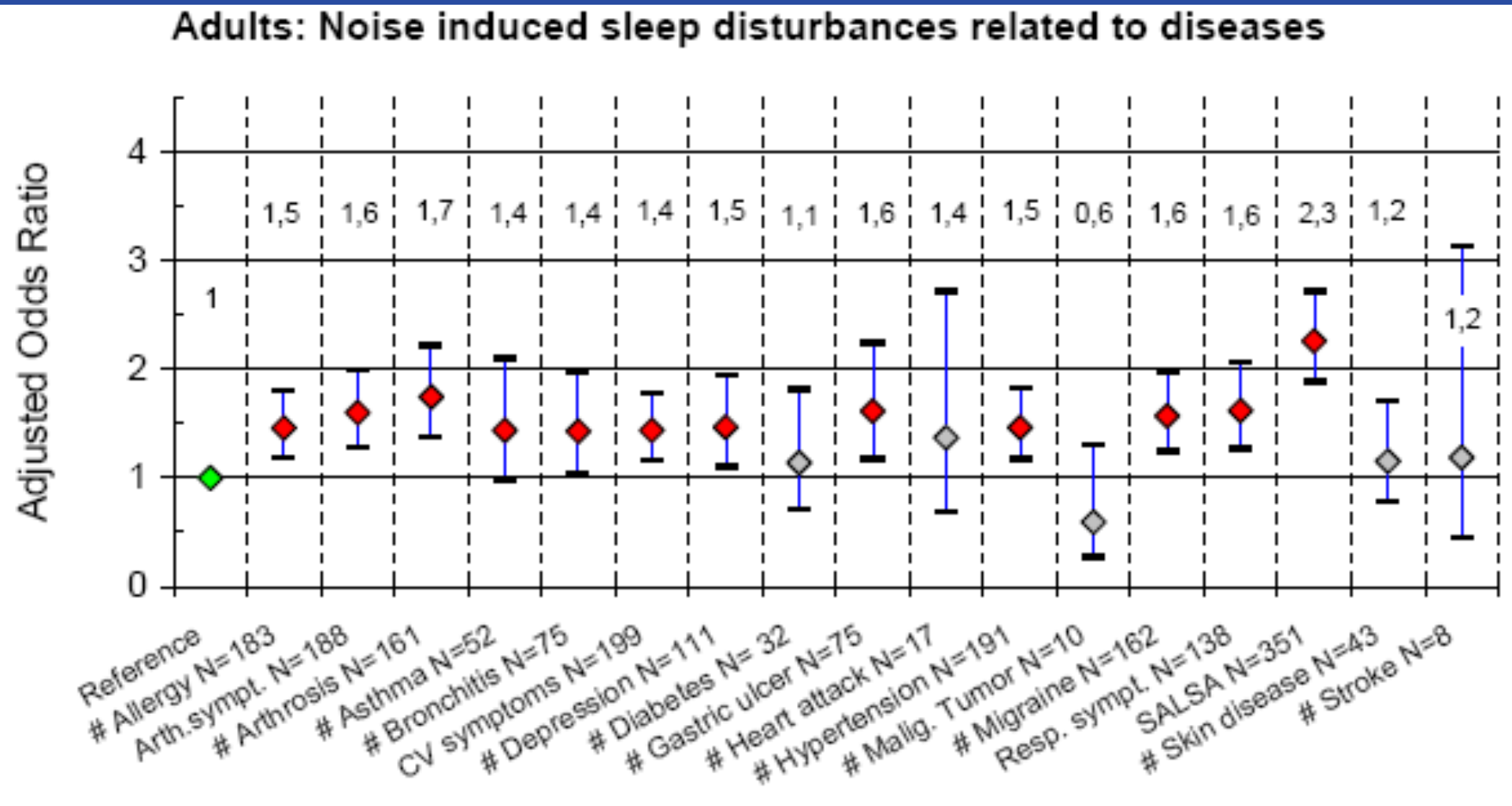
A meta - analysis on sleep duration and mortality



the pooled relative risk (RR) for all-cause mortality for short sleep duration was 1.10 [95% confidence interval (CI): 1.06 - 1.15]

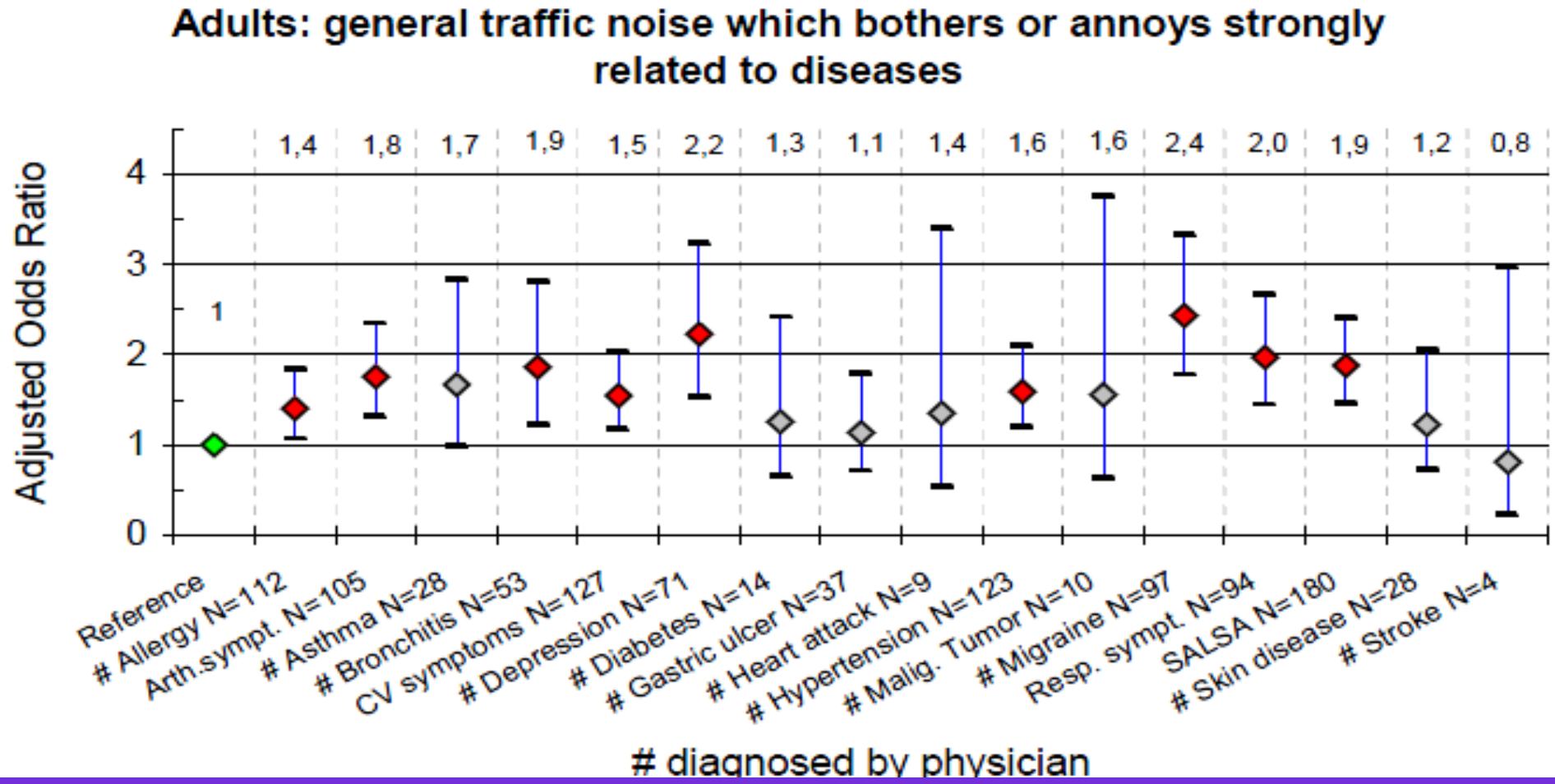
GALLICCHIO L and KALESAN B J. Sleep Res. (2009) 18, 148–158

'Has your sleep been disturbed by noise in the past four weeks?' (18-59yr)



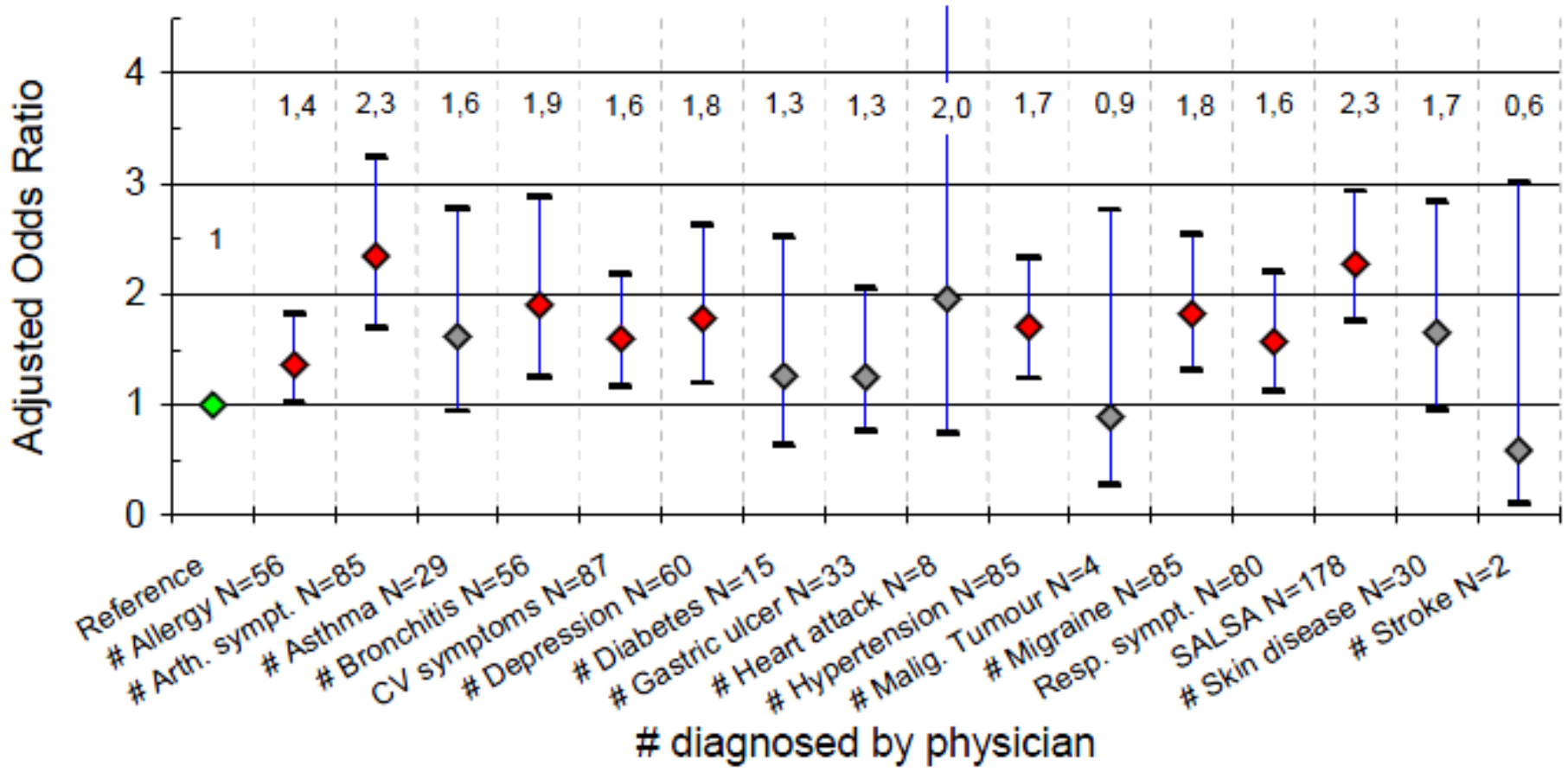
WHO LARES (2004)

LARES: STRONGLY ANNOYED BY TRAFFIC NOISE (18-59 yr)



WHO LARES, 2004

LARES: STRONGLY ANNOYED BY NEIGHBOURHOOD NOISE (18-59 yr)

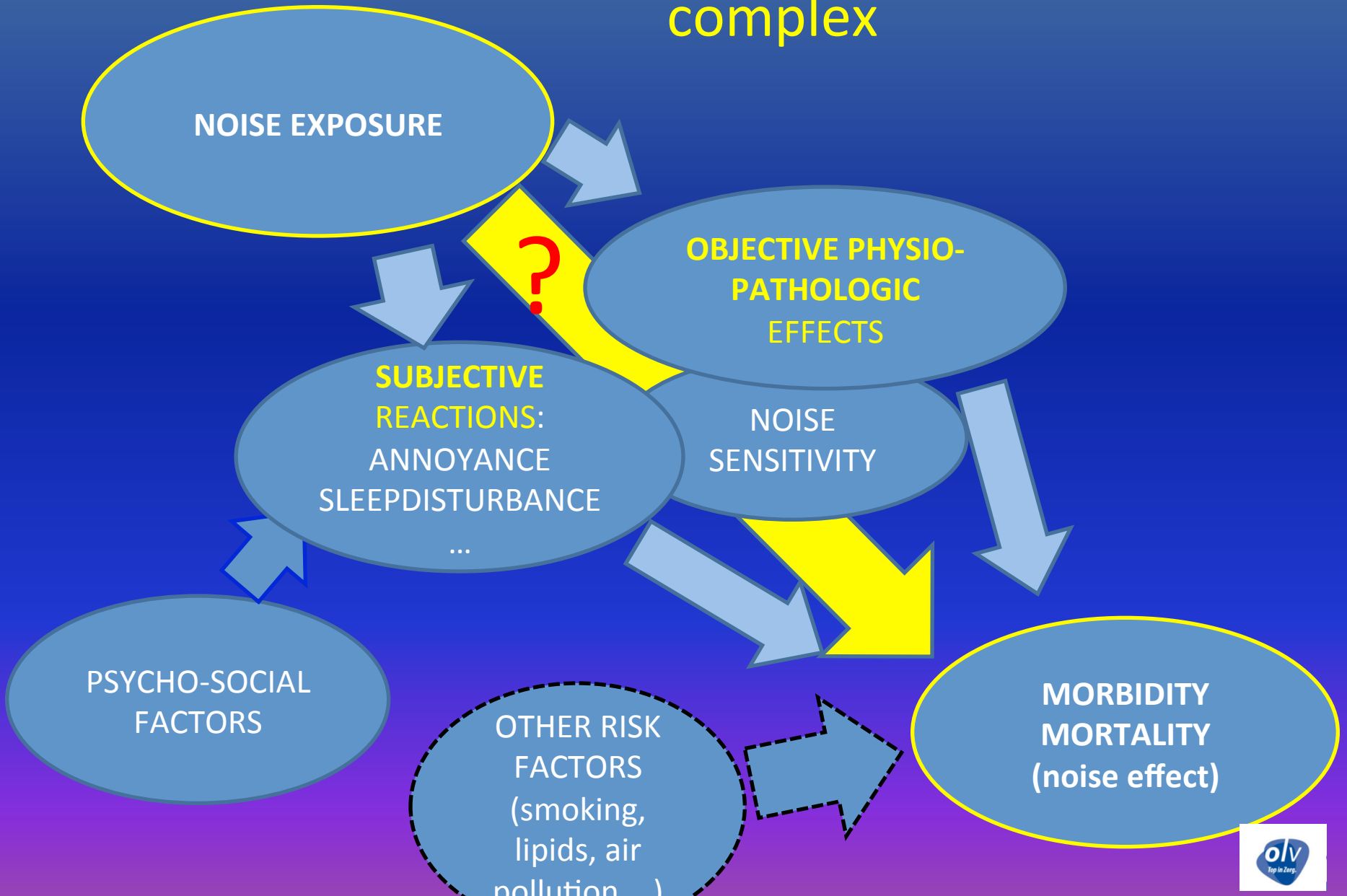


Neighbourhood noise: neighbour flat, staircase, playing chilldren, noise within the dwelling,…

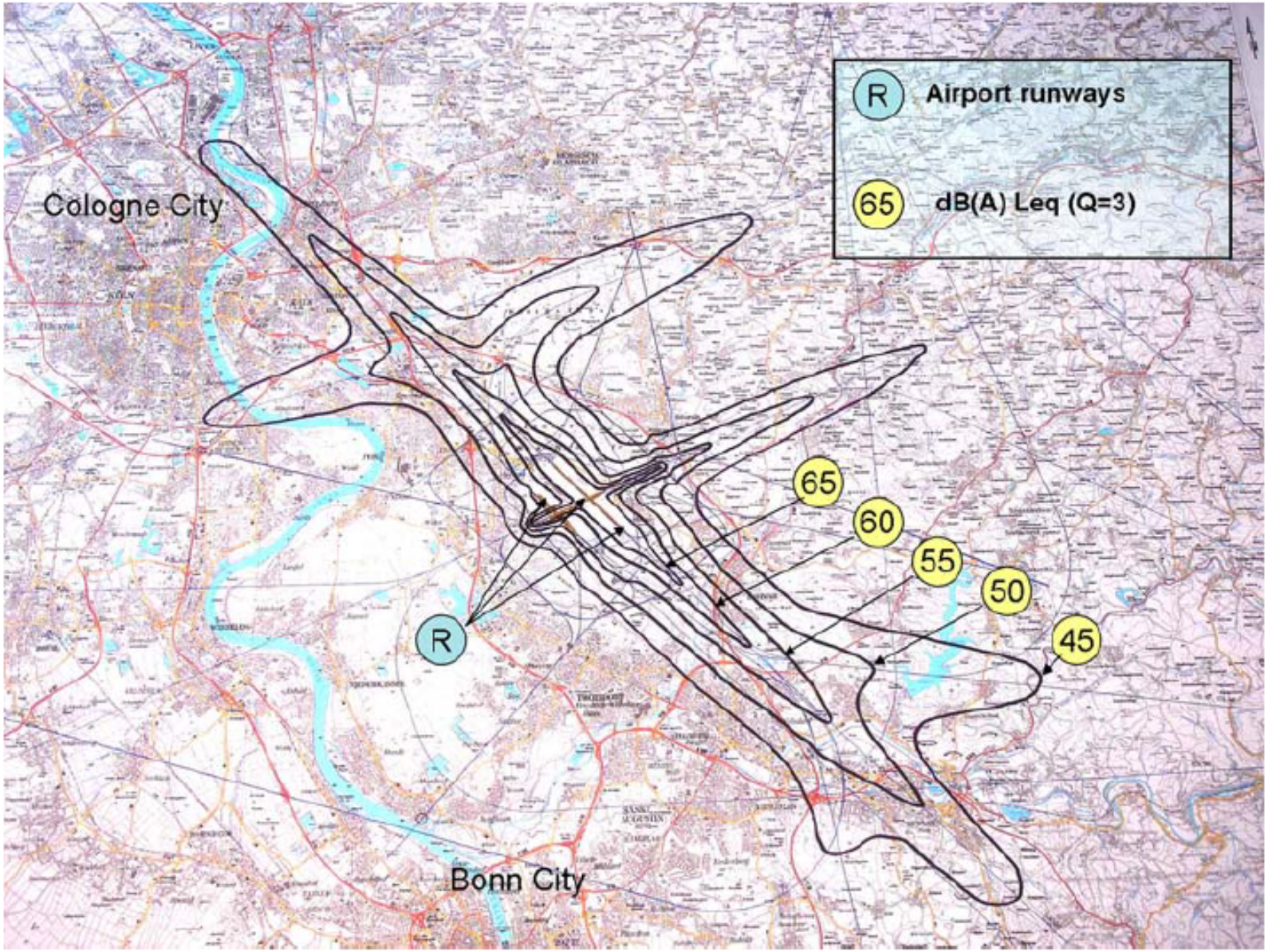
LARES (WHO)

- Strong correlations between
  - sleep disturbance and strong annoyance
  - *AND*
  - disease
- Causality?
  - Dose response effect
  - Biological plausibility
  - Similar relations for traffic and neighbourhood noise

The relationship between noise and health is complex



The Cologne-Bonn Airport study



Greiser et al. J Public Health (2007) 15:327–337

Cardiovascular Risk and Aircraft Noise in Women > 40 year

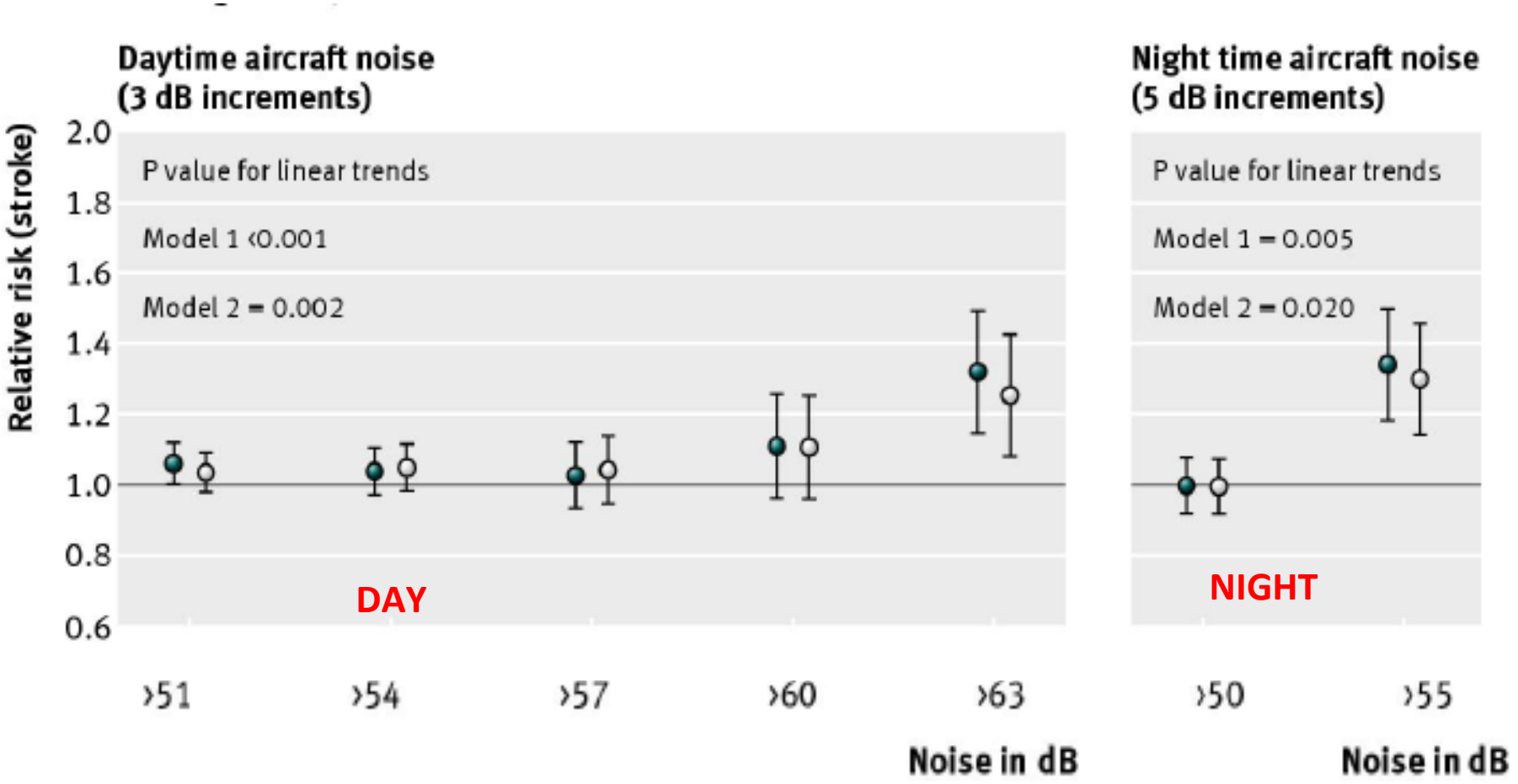
DISEASE	LAeq day >60 dB	Lnight >55dB
CV DISEASES	+ 93%	+115%
STROKE	+ 172%	+ 139%
CORONARY ARTERY DISEASE (STABLE)	+ 80%	+ 110%

OR to develop CV disease
1.055 (CI 1.031-1.082) / 1 dB > 40 Lnight)

Cologne Bonn Airport Noise Study

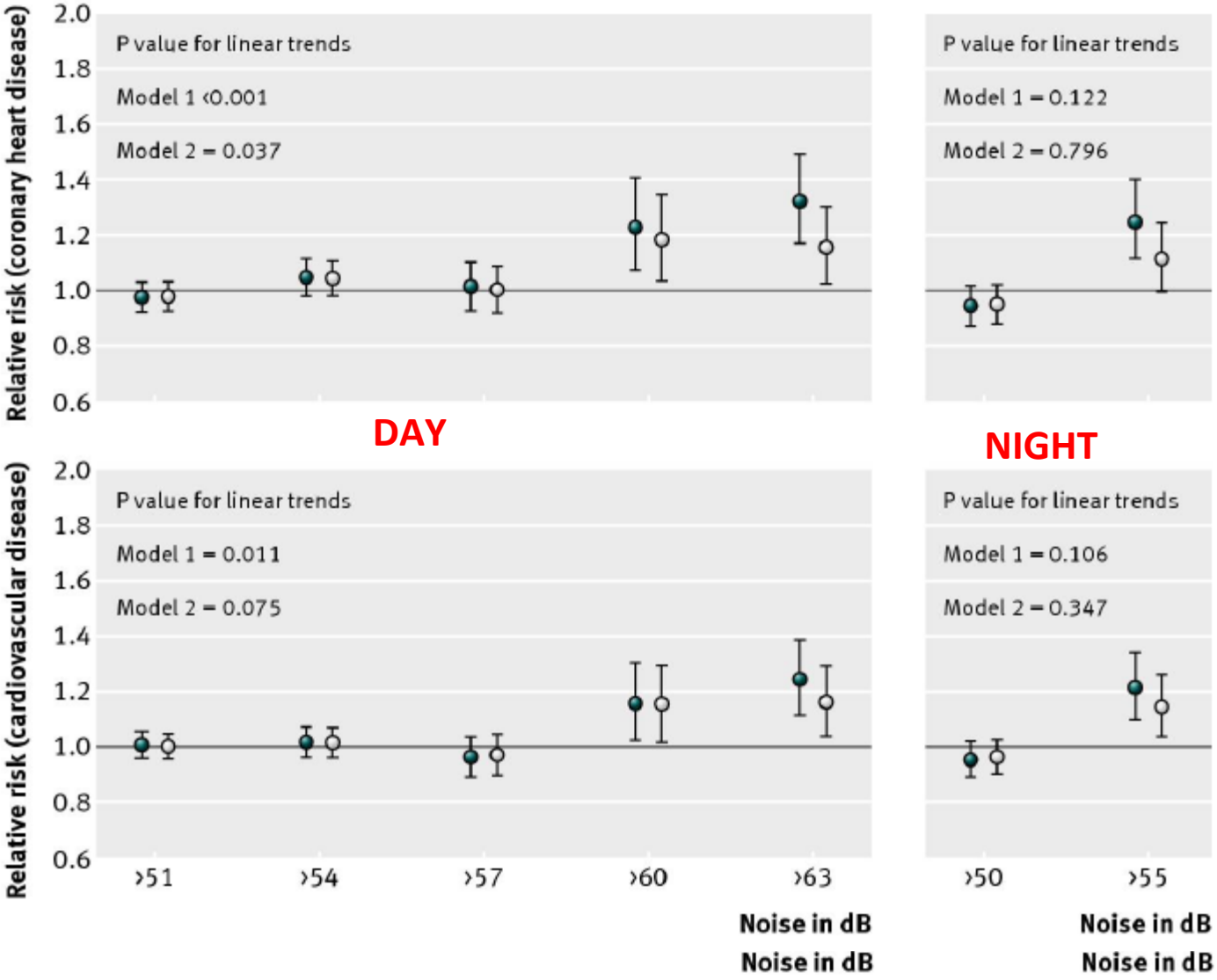
http://www.umweltdaten.de/publikationen/fpdf-l/3774.pdf

Risk of Stroke and Aircraft Noise (Heathrow)



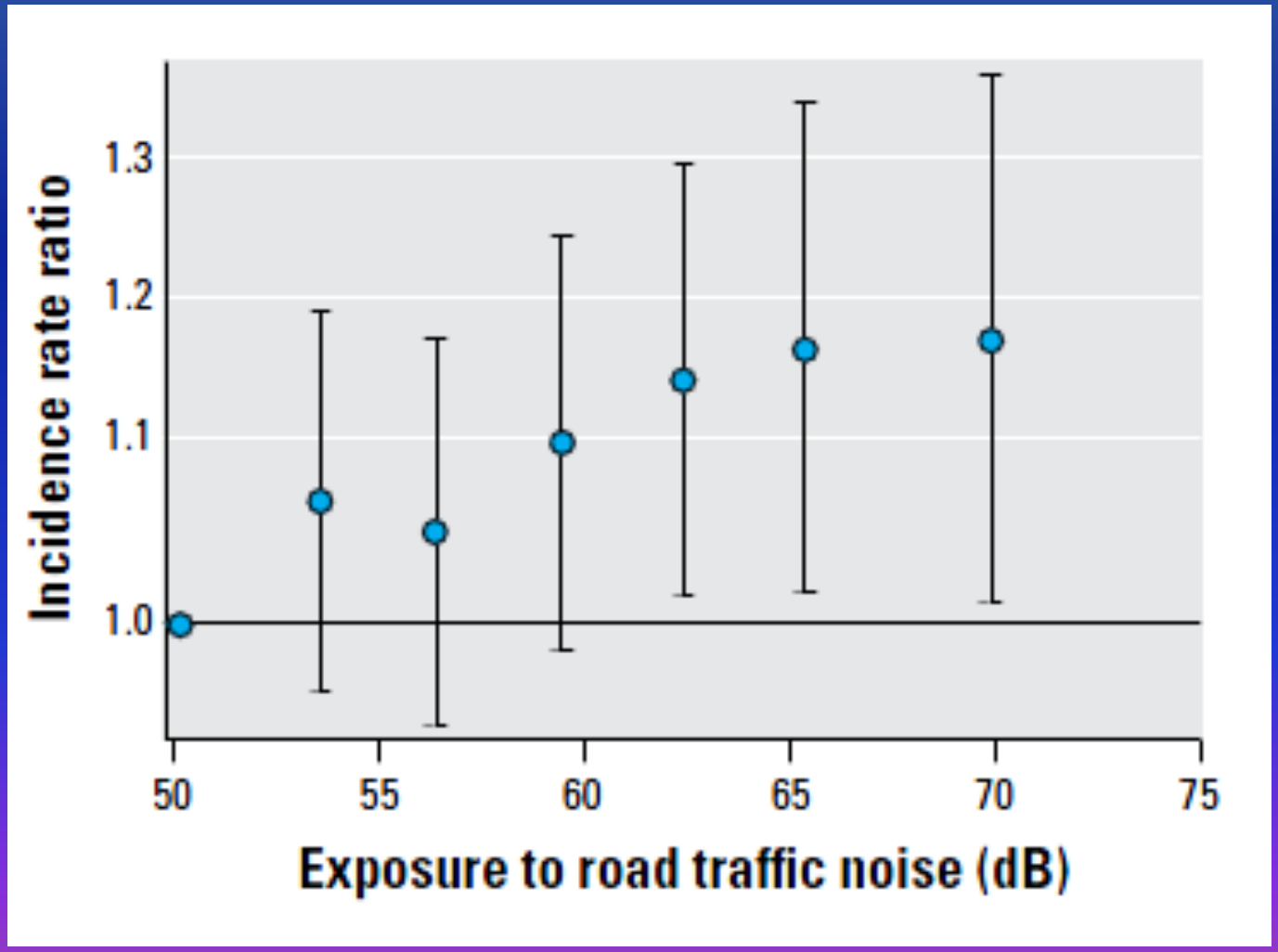
Hansell et al *BMJ* 2013;347:f5432 doi: 10.1136/bmj.f5432

Mortality and Aircraft Noise (Heathrow)



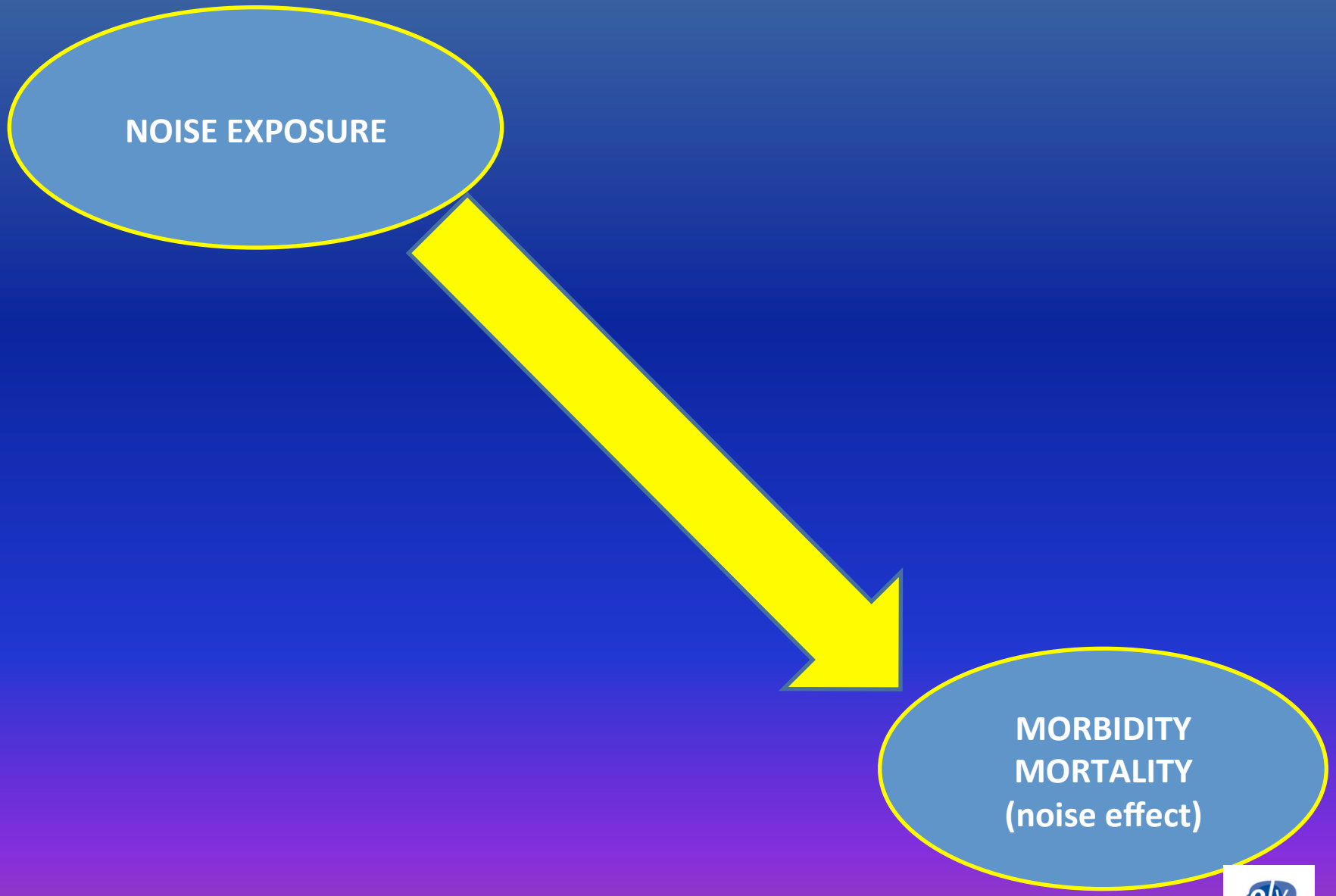
Hansell et al *BMJ* 2013;347:f5432 doi: 10.1136/bmj.f5432

Long-Term Exposure to Road Traffic Noise and Incident Diabetes: A Nation Wide Cohort Study



Mette Sørensen et al. Environ Health Perspect 121:217–222 (2013)

Direct link between decibels and health!



HOW SILENT SHOULD IT BE?

Blood pressure reacts on indoor noise events down to 35 dBA!

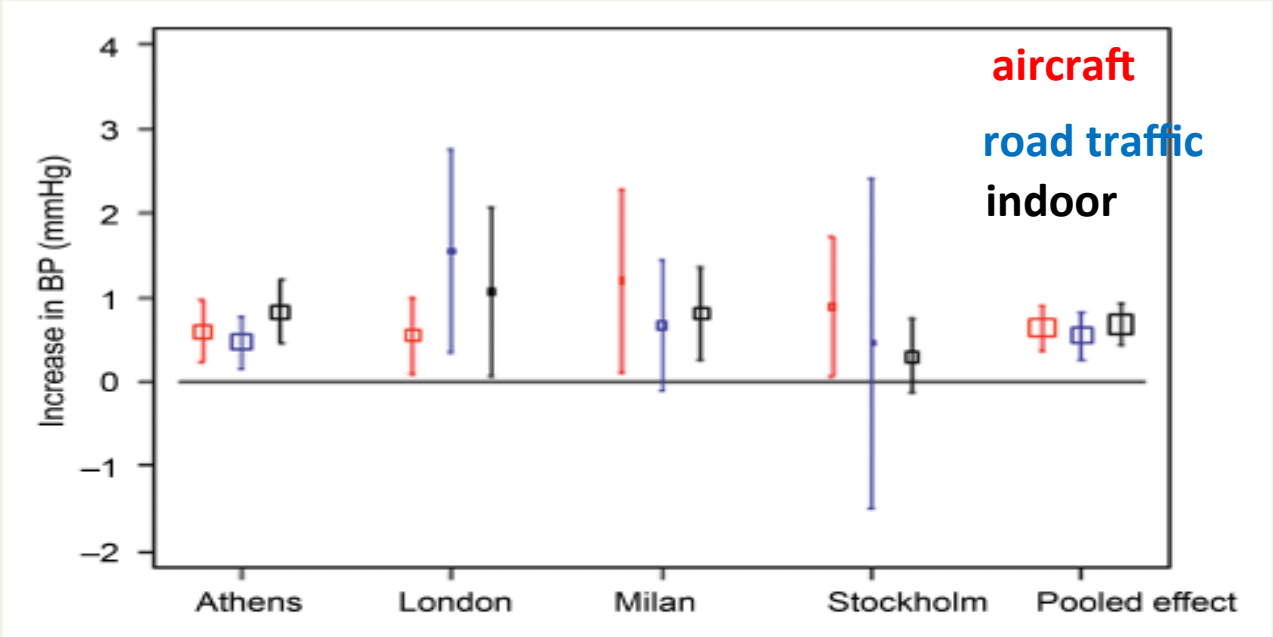


Figure 3 Centre-specific and pooled effect estimates on diastolic blood pressure (BP) and its 95% confidence Interval (CI) associated with an increase of 5 dB in LAmax of aircraft event (red), of road traffic event (blue) and of indoor event (black) during night-time sleep (source-specific event identified as present if indoor measured LAmax > 35 dB)

Haralabidis et al Eur Heart J 2008

Aircraft Noise and Hypertension (HYENA)

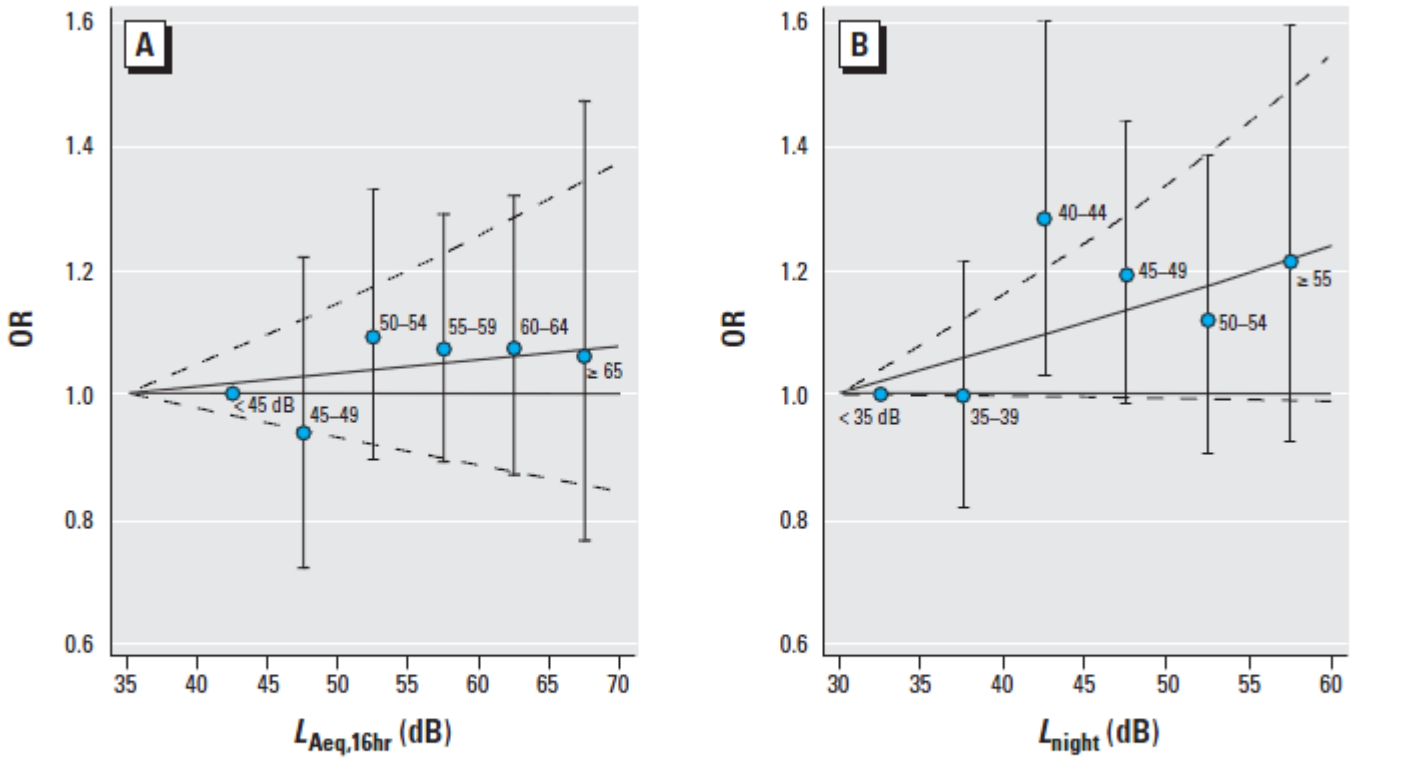


Figure 1. ORs of hypertension in relation to aircraft noise (5-dB categories). $L_{Aeq,16hr}$ (*A*) and L_{night} (*B*) separately included in the model. Adjusted for country, age, sex, BMI, alcohol intake, education, and exercise. The error bars denote 95% CIs for the categorical (5-dB) analysis. The unbroken and broken curves show the ORs and corresponding 95% CIs for the continuous analysis.

Jarup L et al. Environ Health Perspect 116:329–333 (2008)

Night-time Noise Guideline (2009)

- *'… There is no sufficient (DIRECT) evidence that the biological effects observed at the level below 40 dB Lnight,outside are harmful to health.*
- *… However, adverse health effects are observed at the level above 40 dB Lnight,outside , such as self-reported sleep disturbance, environmental insomnia, and increased use of somnifacient drugs and sedatives.*
- *Therefore, 40 dB Lnight,outside is equivalent to the lowest observed adverse effect level (LOAEL) for night noise… '*

Night-time outside noise exposure

	L_{night} in dB				
Country	40–45	46–50	51–55	56–60	61–65+
Switzerland (Müller-Wenk, 2002)	–	24%	14%	7%	2%
Netherlands (Nijland and Jabben, 2004)	25%	31%	19%	6%	1%

Table 1.5 Percentage of dwellings per noise class of L_{night} in dB

WHO night time noise guideline 2009

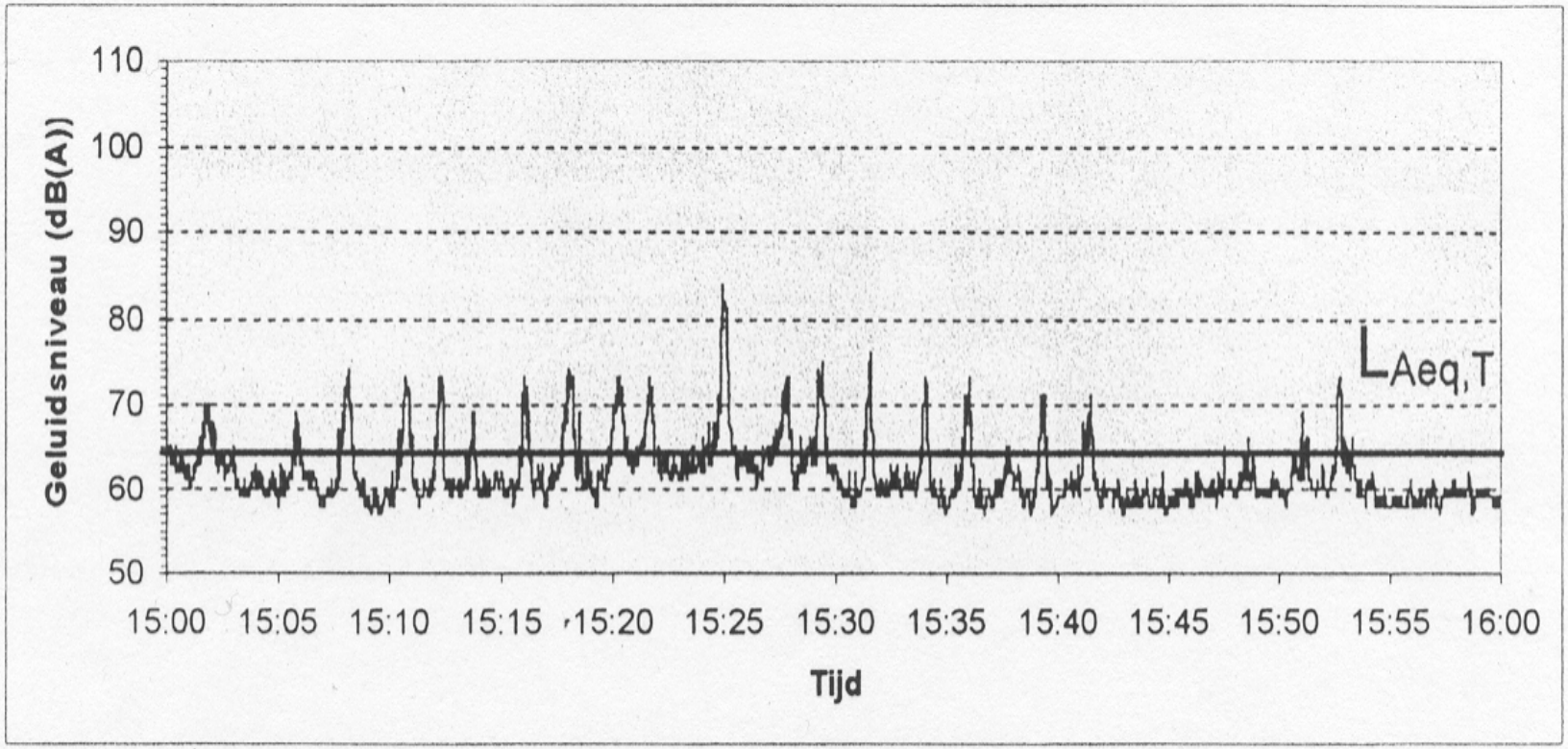
WHO Night-time guidelines

Based on the exposure-effects relationship summarized in Table 3, the night noise guideline values are recommended for the protection of public health from night noise as below.

Night noise guideline (NNG)	$L_{night,outside}$ = 40 dB
Interim target (IT)	$L_{night,outside}$ = 55 dB

Table 4
Recommended night noise guidelines for Europe

What is an A weighted equivalent sound pressure level $L_{Aeq,T}$?



Figuur 1 *Voorstelling van het A-gewogen equivalente geluidsdrukniveau ($L_{Aeq,T}$)*

Serruys P et al. Geluidscontouren rond de luchthaven Brussel-Nationaal 2001

Trading of one ‘very noisy’ B727 for more ‘somewhat less noisy’ aircraft

95 dBA[1]

92 + 92 dBA

89 + 89 + 89 + 89 dBA

86 + 86 + 86 + 86 + 86 + 86 + 86 + 86 dBA

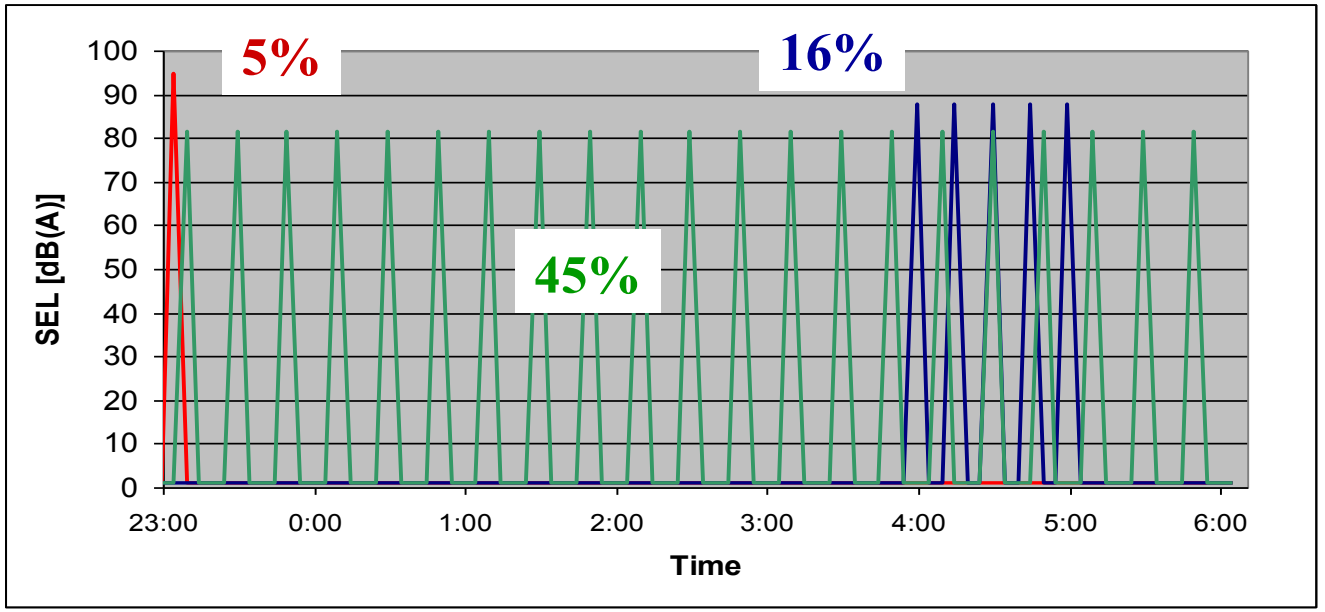
83 + 83 + 83 + 83 + 83 + 83 + 83 + 83 + 83 + 83 + 83 + 83 + 83 + 83 + 83 + 83 dBA

80 + 80 + 80+…. (x 32) ….

Identical $L_{Aeq,23\text{-}06h}$: how do YOU sleep best?

1 : WHO guideline at outside facade = 60 dBA L_{Amax}

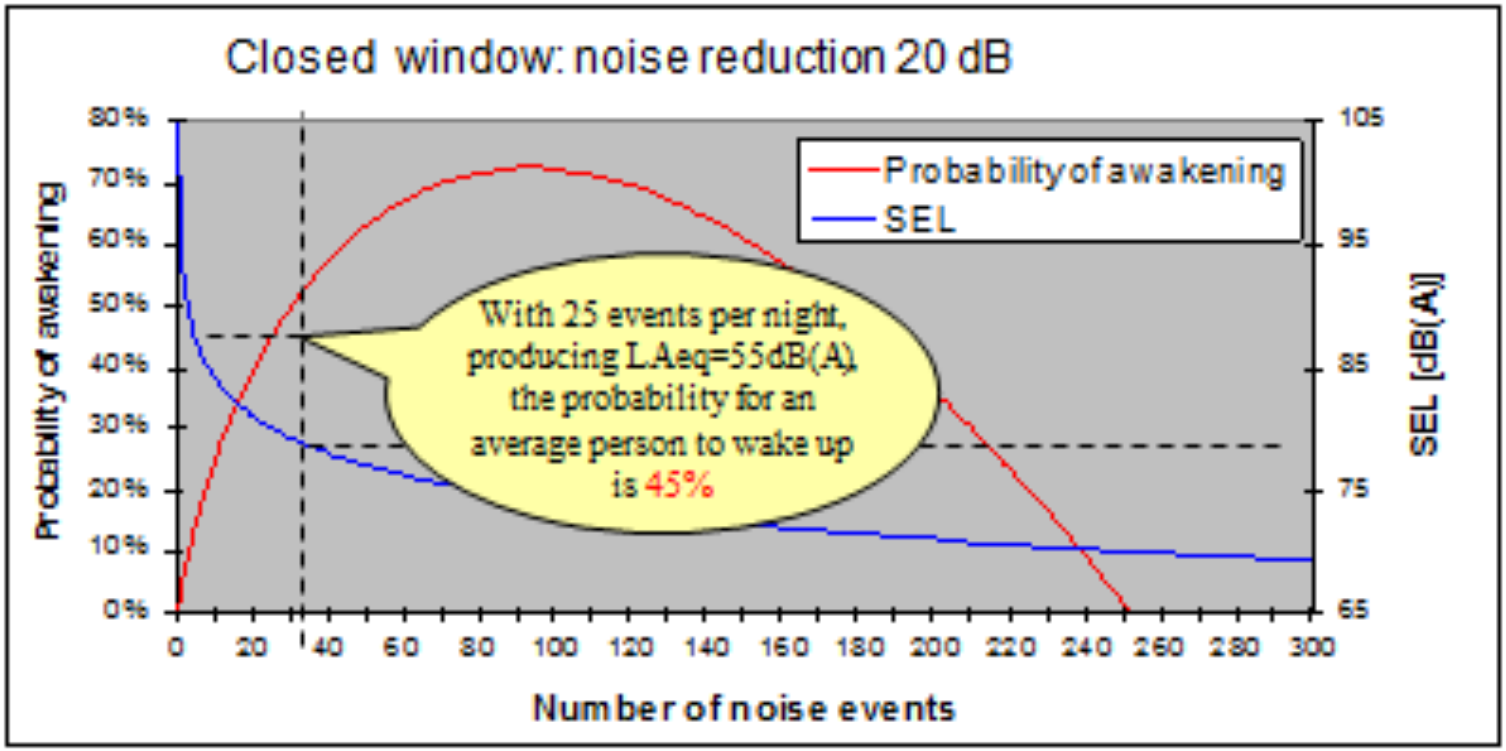
Different Noise Patterns with Identical $L_{Aeq,23\text{-}07h}$ = 55 dBA (outside)



	Scenario 1 (red)	Scenario 2 (blue)	Scenario 3 (green)
Number of events	1	5	21
LAeq	55 dB(A)	55 dB(A)	55 dB(A)
Probability of awakening	1 night on **20**	1 night on **6**	1 night on **2**
Probability of sleep disturbance	1 night on 3	once per night	4 times per night

Calculations assume an open window, 15 dB noise reduction.
Netherlands Health Council 1997: % awakening = 0.0018 x (SEL inside – 55)

Probability of awakening for Lnight 55 dB(A) with number of events



- At identical LAeq the harmfull effects become much more important with increasing number of events !

Calculations assume a closed window, 20 dB noise reduction.

A yearly averaged Lnight of 40 dBA does not protect against sleepdisturbance bij aircraftnoise

Number of events per year corresponding to Lnight of 40 dBA (outside) = 25 dBA (inside)

SEL (dBA)	95	90	85	80	75	70	65	60	55
Number of events per year	1	3	11	33	105	333	1052	3327	10520

Beoordeling van geluidpieken in de woonomgeving'
Miedema en Passchier Vermeer, TNO 1999 (TNO 99.023).

Worst Case Scenario for sleep disturbance

'At a given Lnight value, the most unfavourable situation in terms of a particular direct biological effect of night-time noise is not, as might be supposed, one characterised by a few loud events per night. Rather, the worst case scenario involves a number of noise events all of which are roughly 5 dBA above the threshold for the effect in question..'

The Influence of Night –time Noise on Sleep and Health, **2004**, p 17.

Netherlands Health Council (Nederlandse Gezondheidsraad):

'However, limiting the SEL inside the bedroom to less than the biological effect threshold levels is not a technically realistic option at the present time. Depending on how Lnight is regulated, one option might also be to limit the number of noise events'

An Lnight/Laeq does not garantee health protection but creates the illusion of economic growth with less impact on health!

The characteristics and number of individual events should be taken into account!

EU directive 2002/49

The selected common noise indicators are Lden, …/… and Lnight, … It is also useful to allow Member States to use supplementary indicators in order to monitor or control special noise situations

EU noise exposure- response curve for annoyance (Lden)

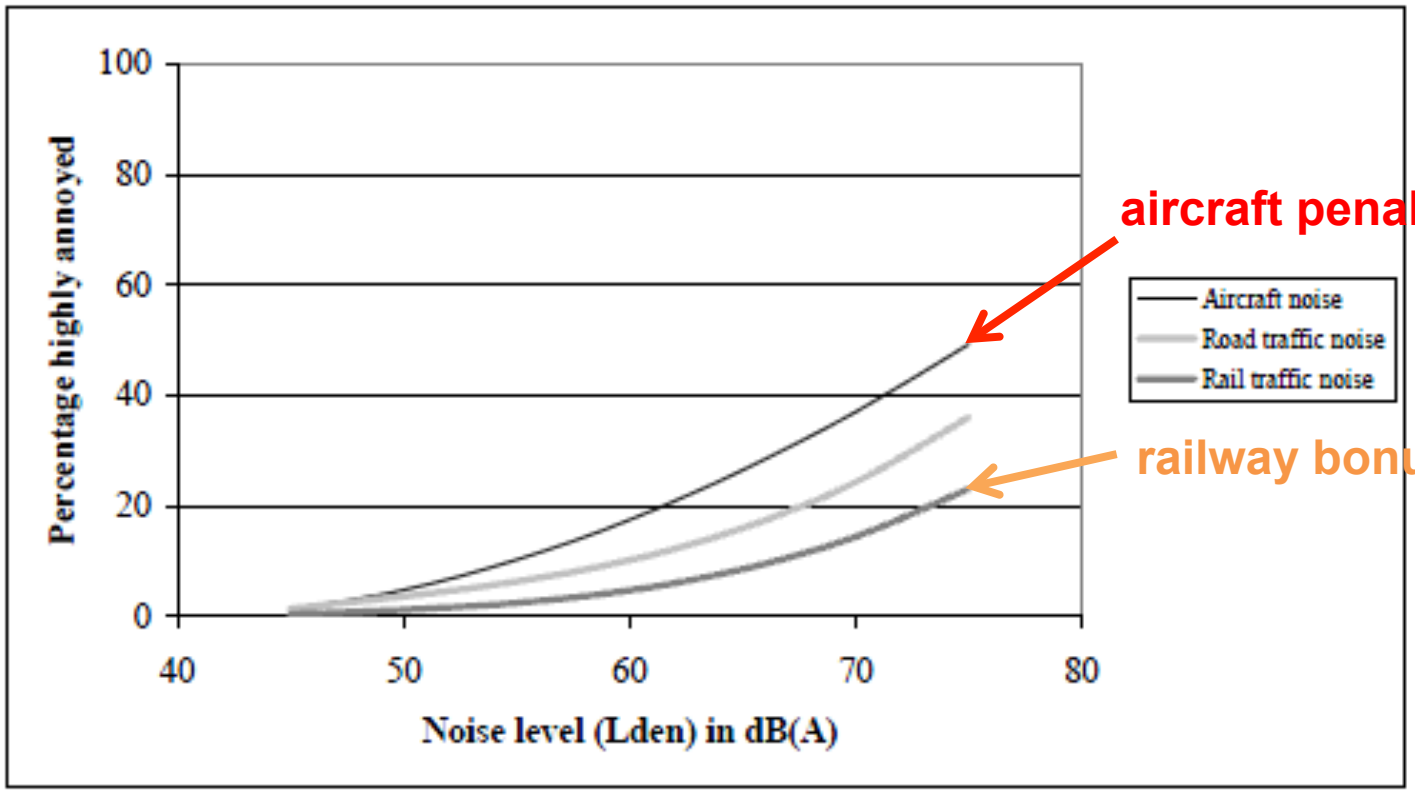
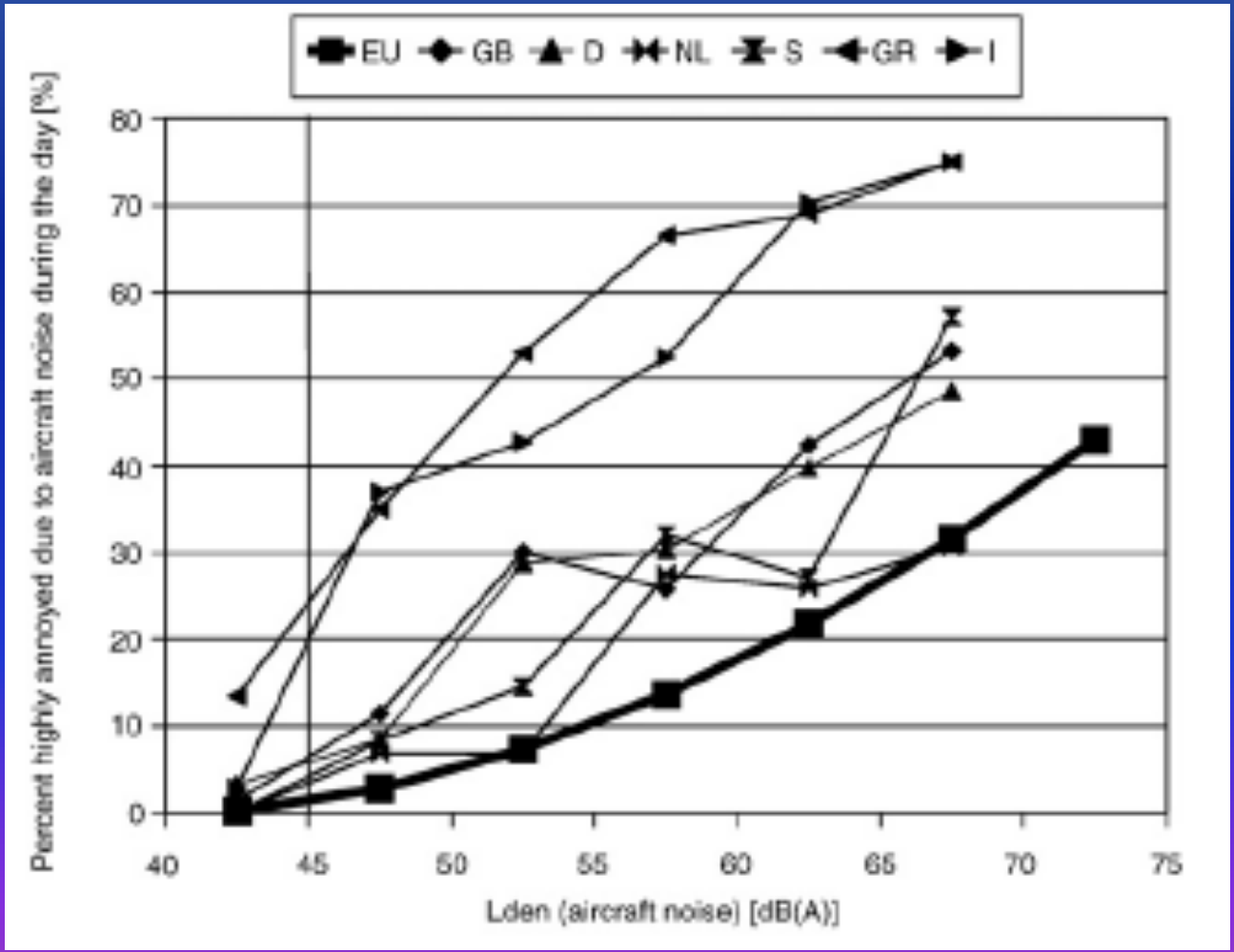


Figure 3. Exposure-effect-relationships for the association between noise (expressed as L_{den}) from different sources and annoyance derived by Miedema and Oudshoorn (2001).

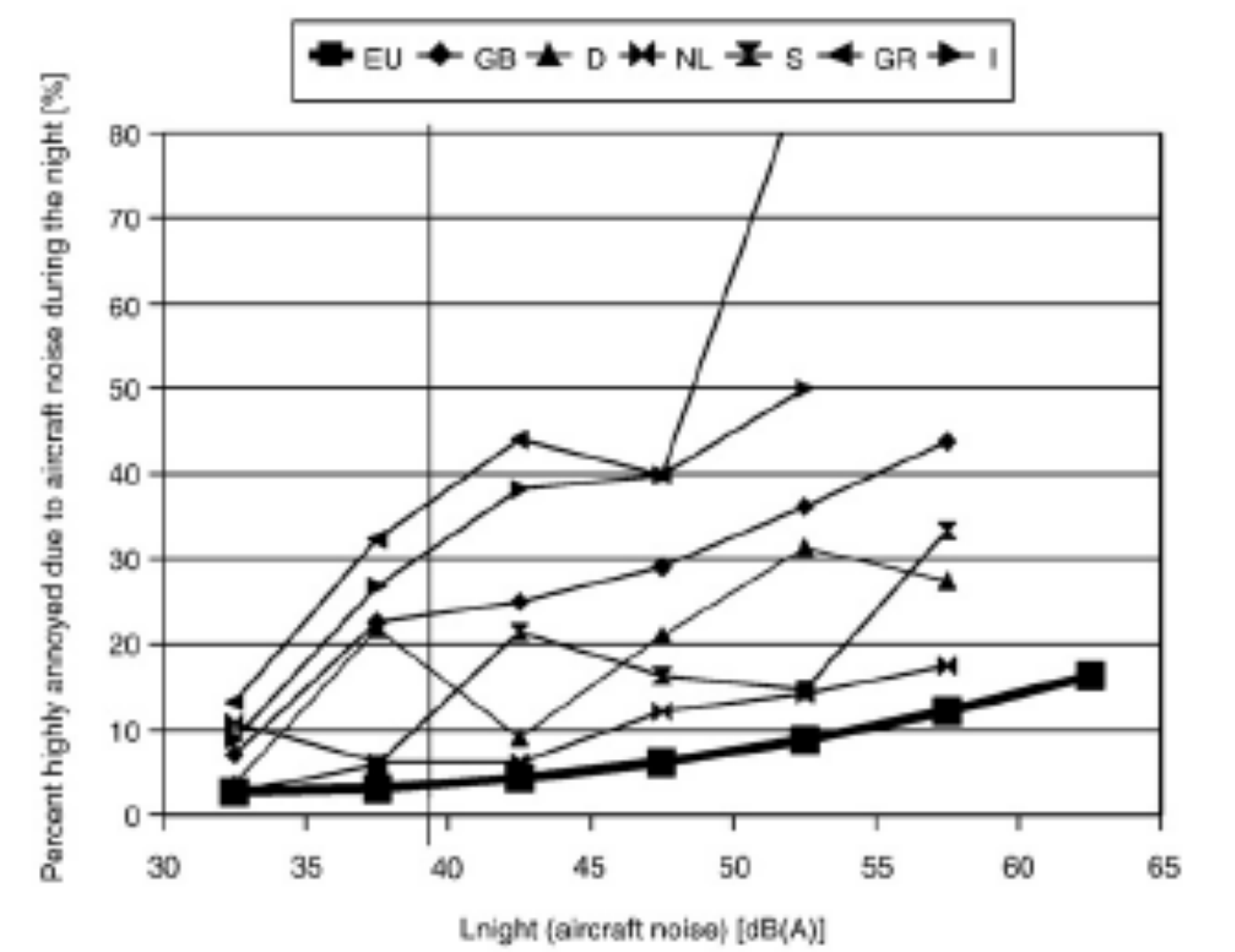
Miedema en Oudshoorn 2001

Noise exposure- response for annoyance in real life



Babisch W et al Environment International 2009 (HYENA)

EU noise exposure response curve for sleepdisturbance (Lnight) in real life



Babisch W et al Environment International 2009 (HYENA)

Why did percentage annoyed/ sleepdisturbed increase?

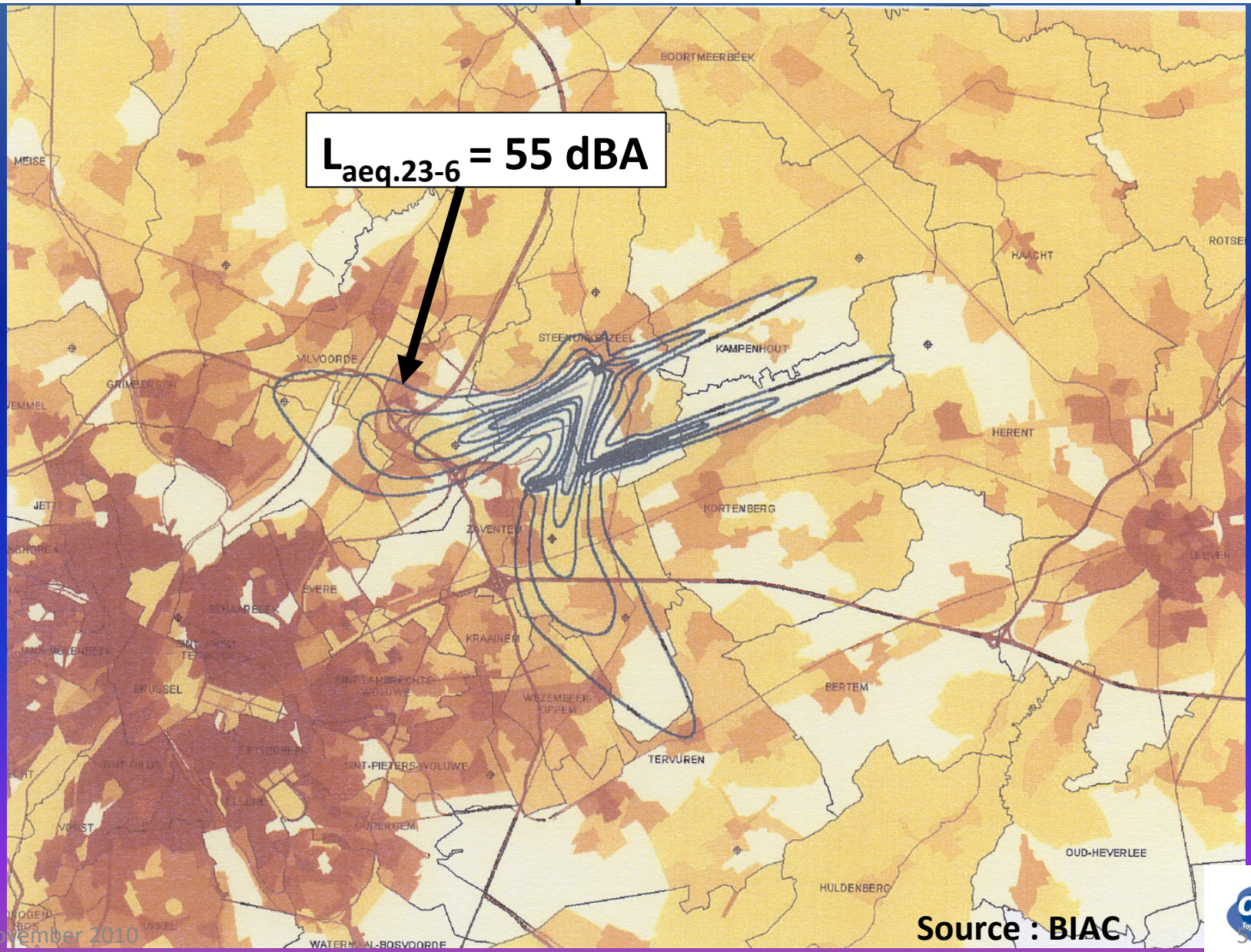
- The Miedema/EU noise exposure response curve was obtained by meta-analysis of 20 studies between 1965 and 1992 (17/20 before 1985, i.e. before the boom of air traffic, 'outliers' were disgarded)
- To day the same quotum of Lnight is obtained with many more events than before 1985 because aircraft became slightlly less noisy (but remain still noisy)
- Events occur so frequently that they cannot be considered 'independent'
- The illusion that sound insulation was protective caused concentration of flight movements creating a worst case scenario

What knew Belgian politicians already in 2000?

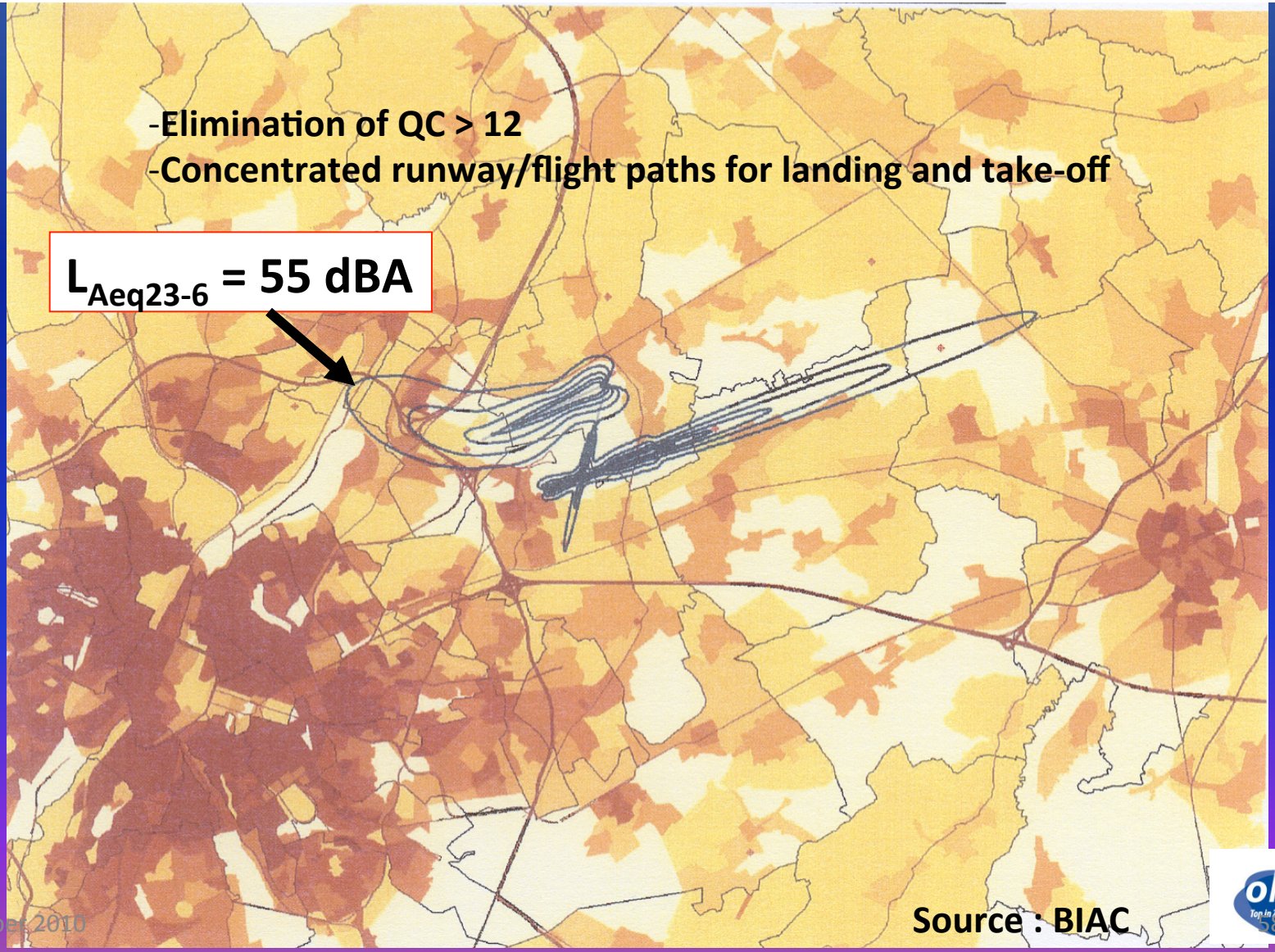
*'La **concentration** des trajectoires **pendant la journée** générerait localement un tel niveau de nuisances sonores et autres, s' il était effectivement concentré au-dessus de quelques bandes du territoire qu'on peut estimer **qu'une bonne partie de celles-ci en deviendraient de facto inhabitables**. Une telle stratégie ne peut par conséquent être envisagée dans l'immédiat. Cette position pourrait toutefois être revue à l'avenir en fonction des résultats des programmes d'isolation et d'expropriation...'*

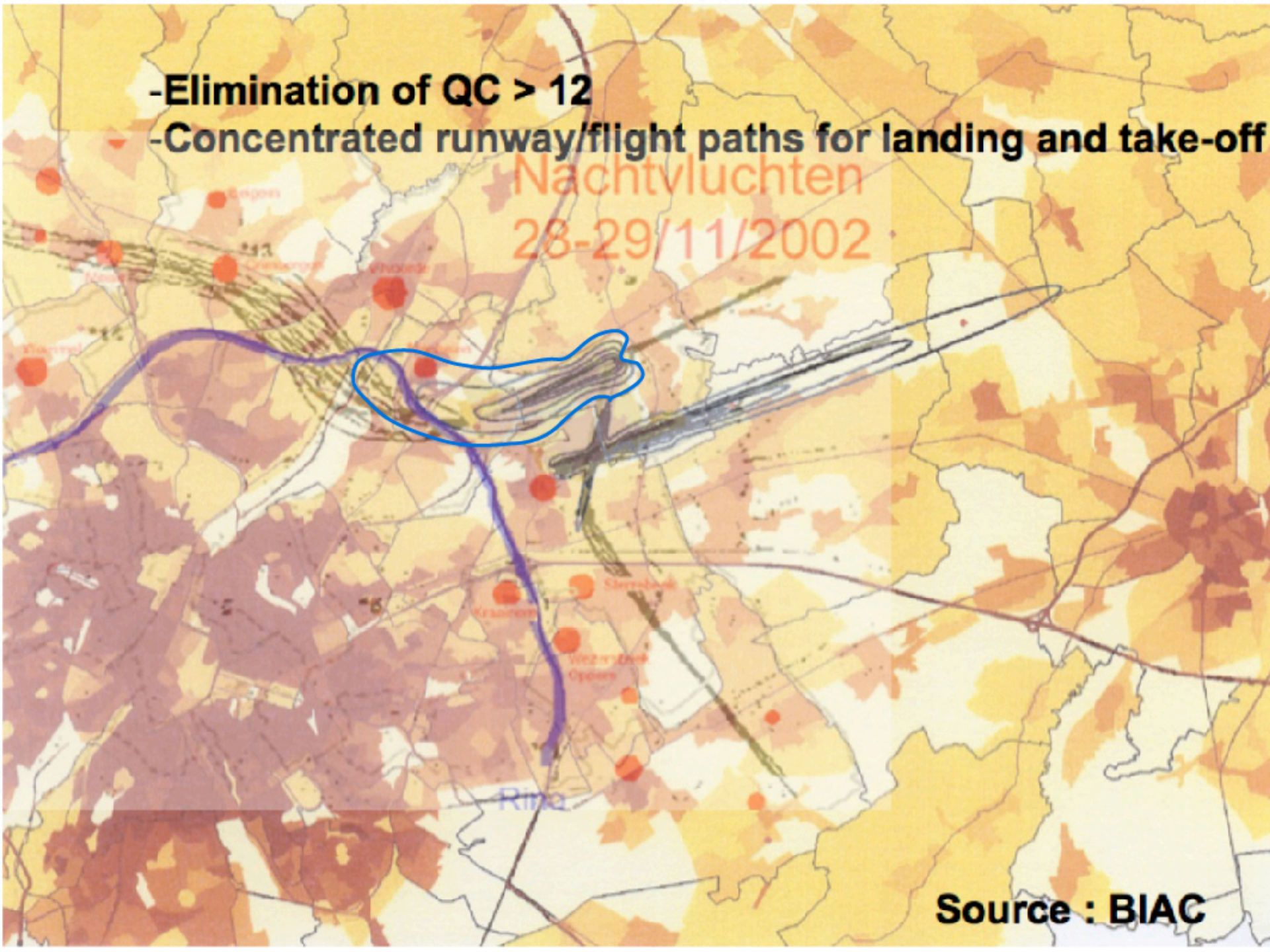
Groupe de Travail Interministeriel
PROBRU 18 septembre 2000

Noise Contour Map : $L_{Aeq\ 23\text{-}06h}$ 55 dBA: 2000



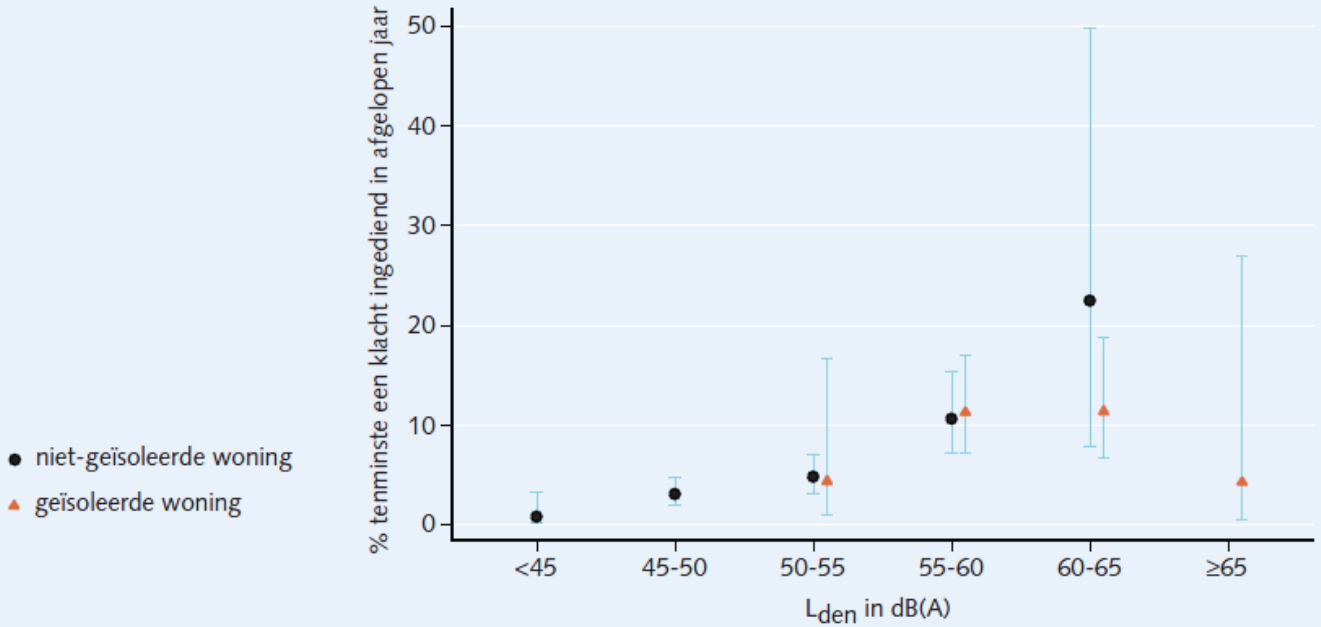
Predicted Noise Contour Map : LAeq 23-06h 55 dBA: 2003




-Elimination of QC > 12
-Concentrated runway/flight paths for landing and take-off
Nachtvluchten
28-29/11/2002
Ring
Source : BIAC

Has sound insulation an influence on annoyance (complaining)?

Figuur 6-1 Het percentage één of meer malen klagen in de afgelopen 12 maanden in 2005 in de regio Schiphol uitgesplitst naar L_{den} en de geluidsisolatie, inclusief het 95% betrouwbaarheidsinterval



Evaluatie Schipholbeleid 2005

Influence of Sound Insulation on Sleepdisturbance (Okinawa)

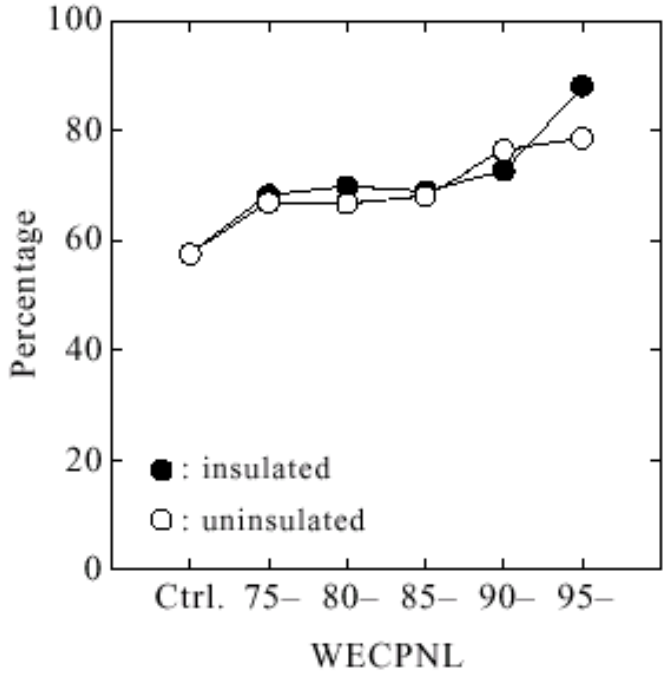
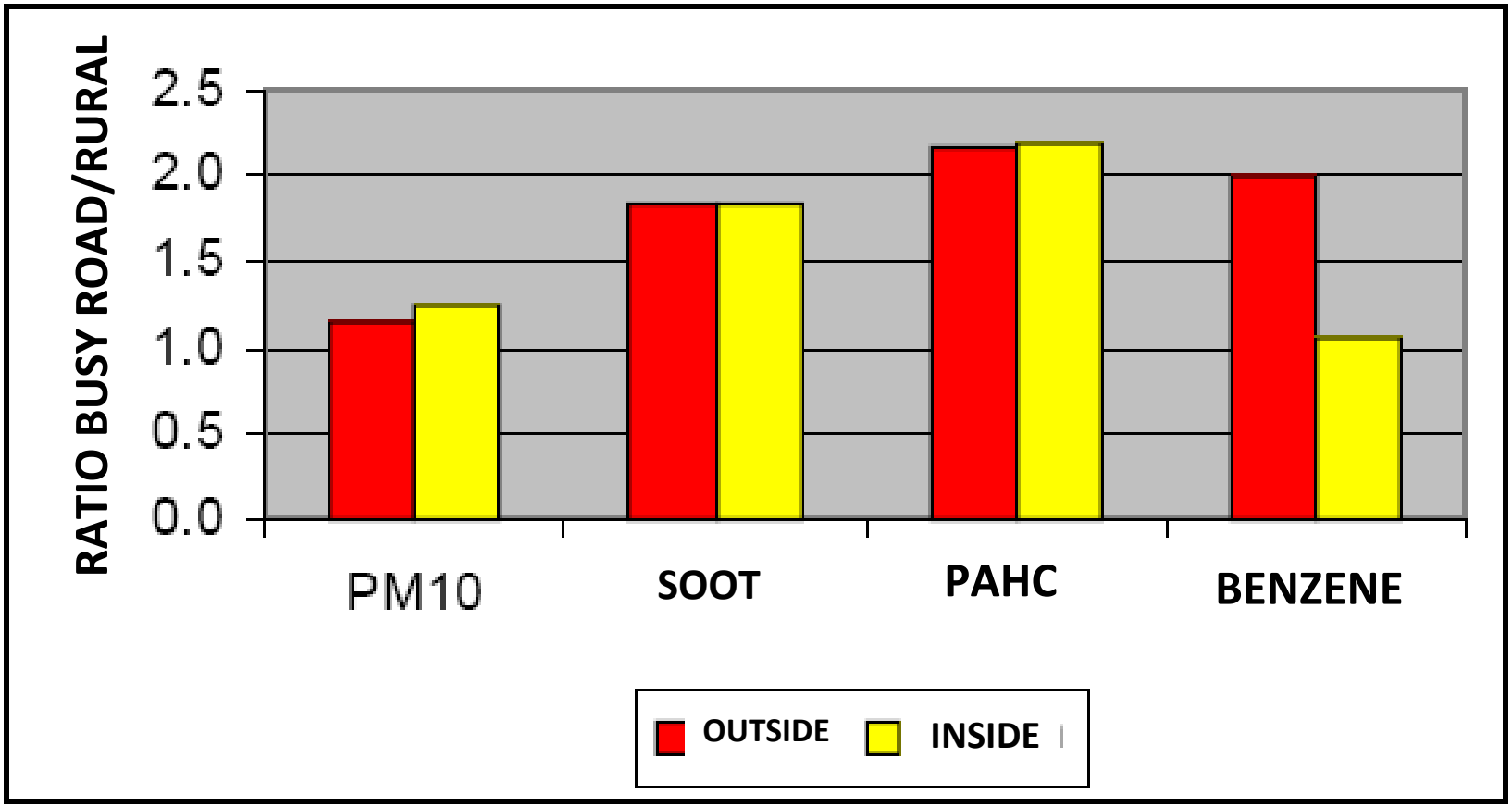


Figure 4.6 Percentage of the scores on the sleep disorders "Once or more a month" *vs.* WECPNL in relation to sound insulation.

AIR and NOISE POLLUTION…

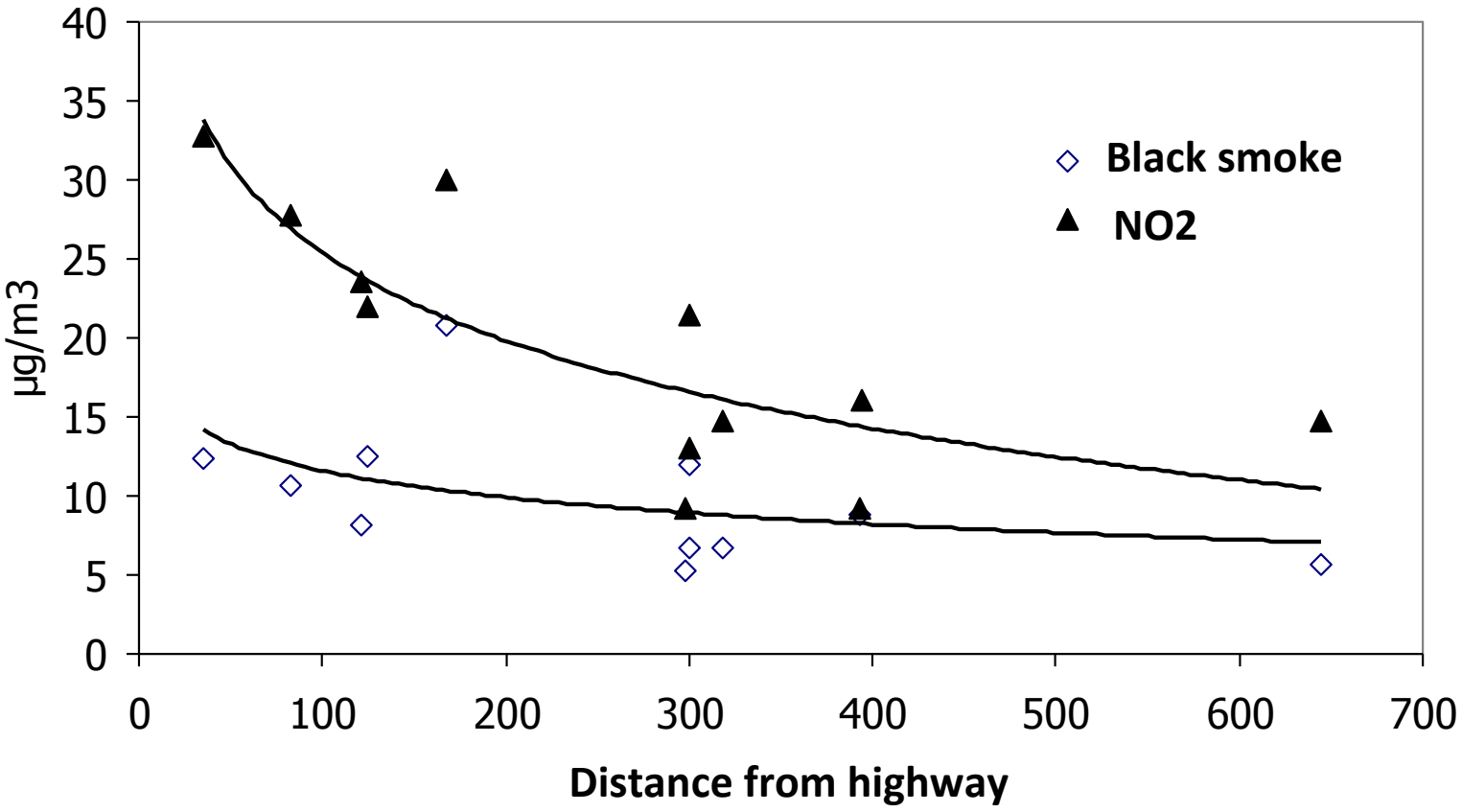
PARTNERS IN CRIME!

AIR POLLUTION OUTSIDE AND INSIDE HOUSES IN RURAL AND BUSY ROAD CONDITIONS



Fischer et al Atmos Environ 2000;34:3713-22

BLACK SMOKE AND NO2 INSIDE SCHOOLS near HIGHWAYS



Fischer et al VROM 2007: Invloed van de afstand tot een Drukke verkeersweg op de lokale luchtkwaliteit en gezondheid

HEI rapport (2010)

- The panel identified *an exposure zone within a range of up to 300 to 500 m from a highway or a major road* as the area most highly affected by traffic emissions (the range reflects the variable influence of background pollution concentrations, meteorologic conditions, and season) and estimated that *30% to 45% of people living in large North American cities live within such zones.*

HEI= Health Effects Institute

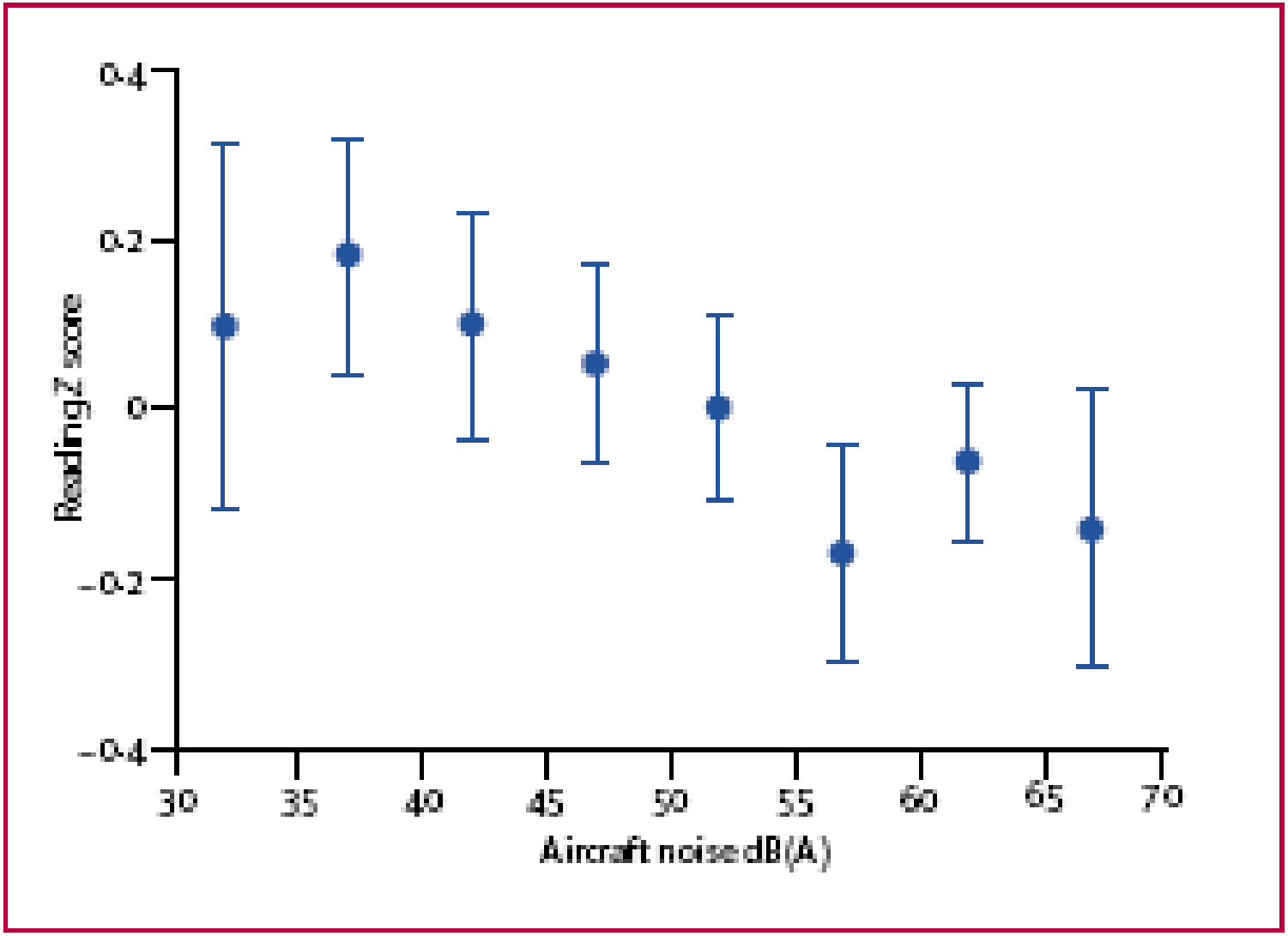
Conclusions (1)

- Environmental noise is a serious threat to our health
- Undisturbed sleep (in silence) is a human right because it is an essential element for health
- Annoyance or subjective sleepdisturbance is not an obligatory mediator of disease
- Noise exposure has a direct link to morbidity and mortality
- The human ear is extremely sensitive to noise (noise events down to 32- 35 dBA provoke autonomous reactions of the human body) Very probably disease is mediated by autonomous reactions to noise for which habituation does not occur
- The worst case scenario occurs with frequent noise events slightly above the threshold of the effect (e.g. sleepdisturbance, awakening, annoyance,..)
- Therefore, sound insulation of dwellings , will be very demanding in case of high intensity, low frequency content and frequent events

Conclusions (2)

- Large scale evaluations of sound insulation around airports do not show significant impact on annoyance, complaining, sleep disturbance because low frequency content of aircraft noise, ventilation problems and sound insulation comes together with concentration of airtraffic (worst case scenario)
- Around airports concentration of flight paths can only be justified in uninhabitated corridors (extended over 20 – 30 kilometers from the runway) or if expropriation is feasable, soundinsulation is not an option: worst case scenario
- Exposure of traffic noise can only be controlled by limitation of traffic and separation of habitation from the traffic
- We should aim not only for silent areas but also for common silent periods during night and weekend
- In view of very close relation between air pollution and noise pollution (vicinity of traffic) ventilation and filtering of air will be the greatest challenge

RANCH: daytime aircraft noise impairs reading ability in school children



Clark et al. Am J Epidemiol 2006;163:27–37

The human body reacts autonomously to noise day and night

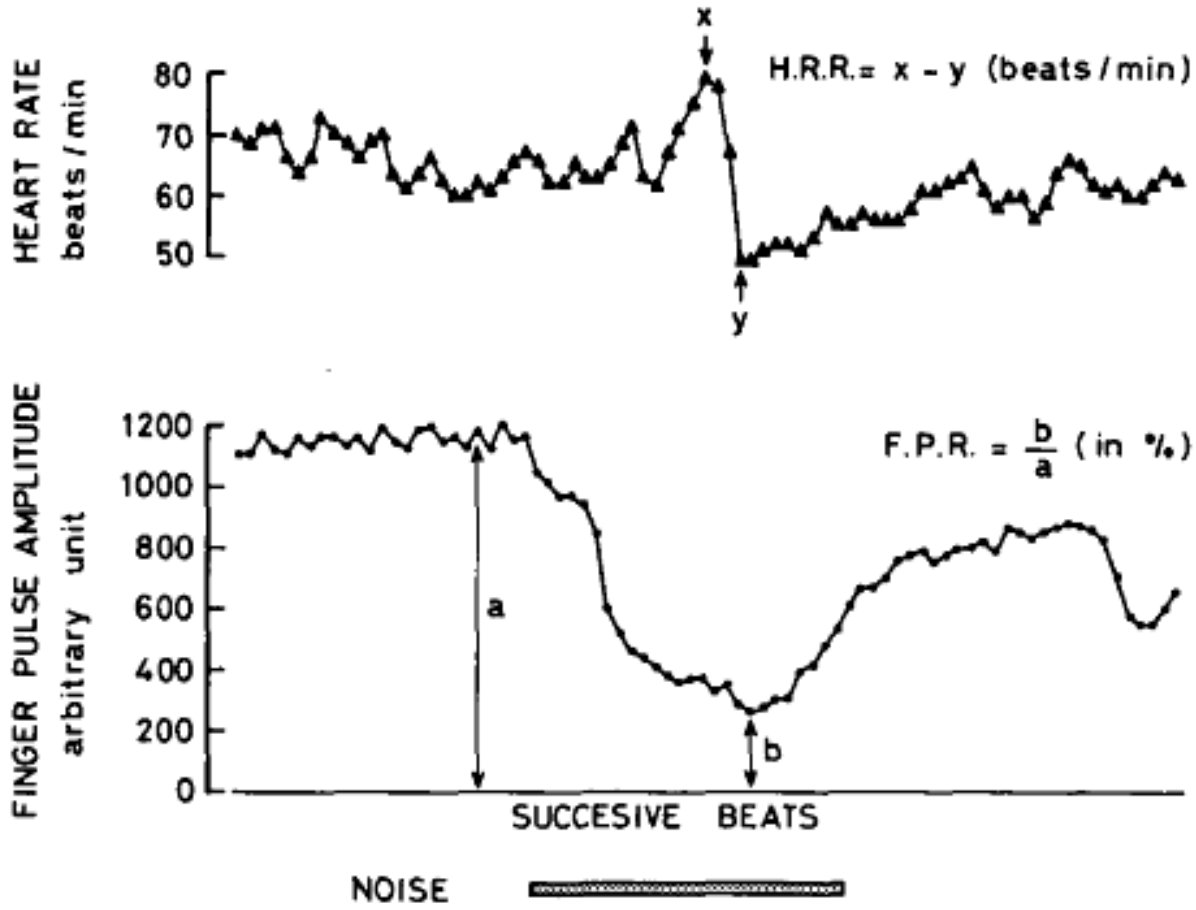
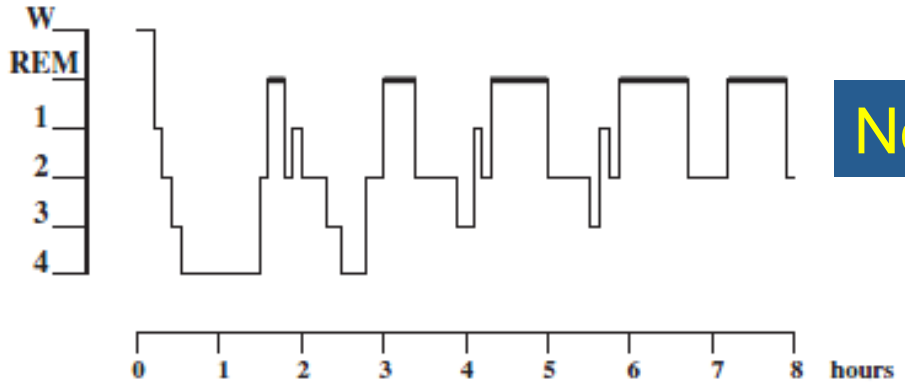


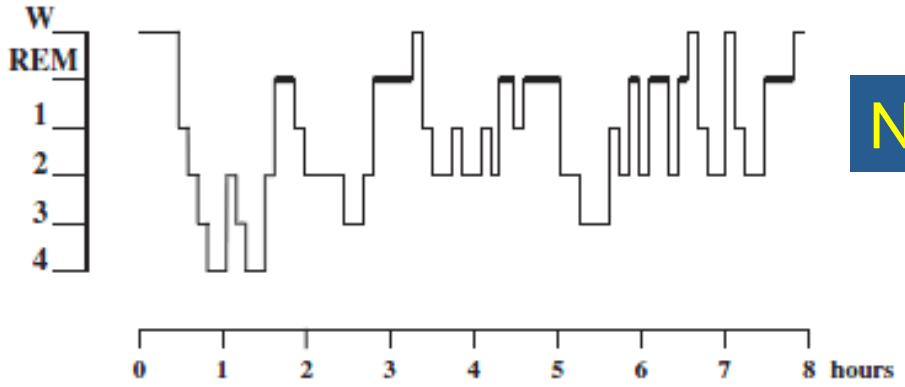
FIG. 3. Examples of heart-rate response (HRR) and finger pulse response (FPR) induced by noise.

Di Nisi et al. Comparison of cardiovascular responses to noise during waking and slieeping in humans SLEEP 1990:13:108

Sleep disturbance by noise (polysomnogram)



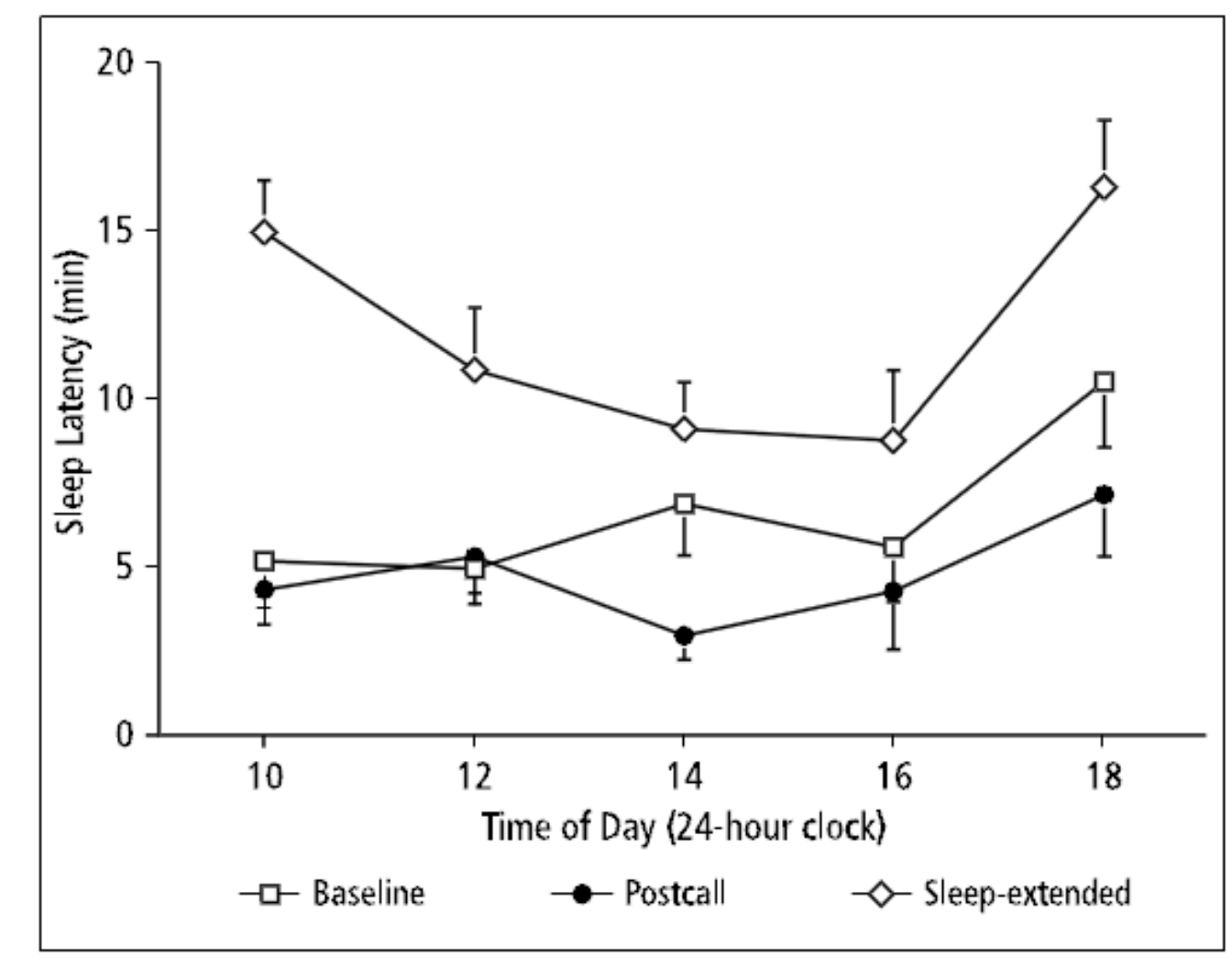
Normal night



Noisy night

Muzet A. Environmental Noise, Sleep and Health Sleep Medicine Reviews 2007:11:135

Sleep latency in anesthesiology residents



Howard S Sleep deprivation and physician performance
BUMC PROCEEDINGS 2005;18:108–112

One hour extra sleep per night

- Decreases 5 year incidence of coronary artery calcification with 33% (OR 67, CI 0.49-0.91)
- Has preventive effects comparable to a lowering of systolic bloodpressure with 16.5 mm Hg!

King R et al. JAMA 2008;300: 2859-2865

Coronary Calcium Score and CIHL

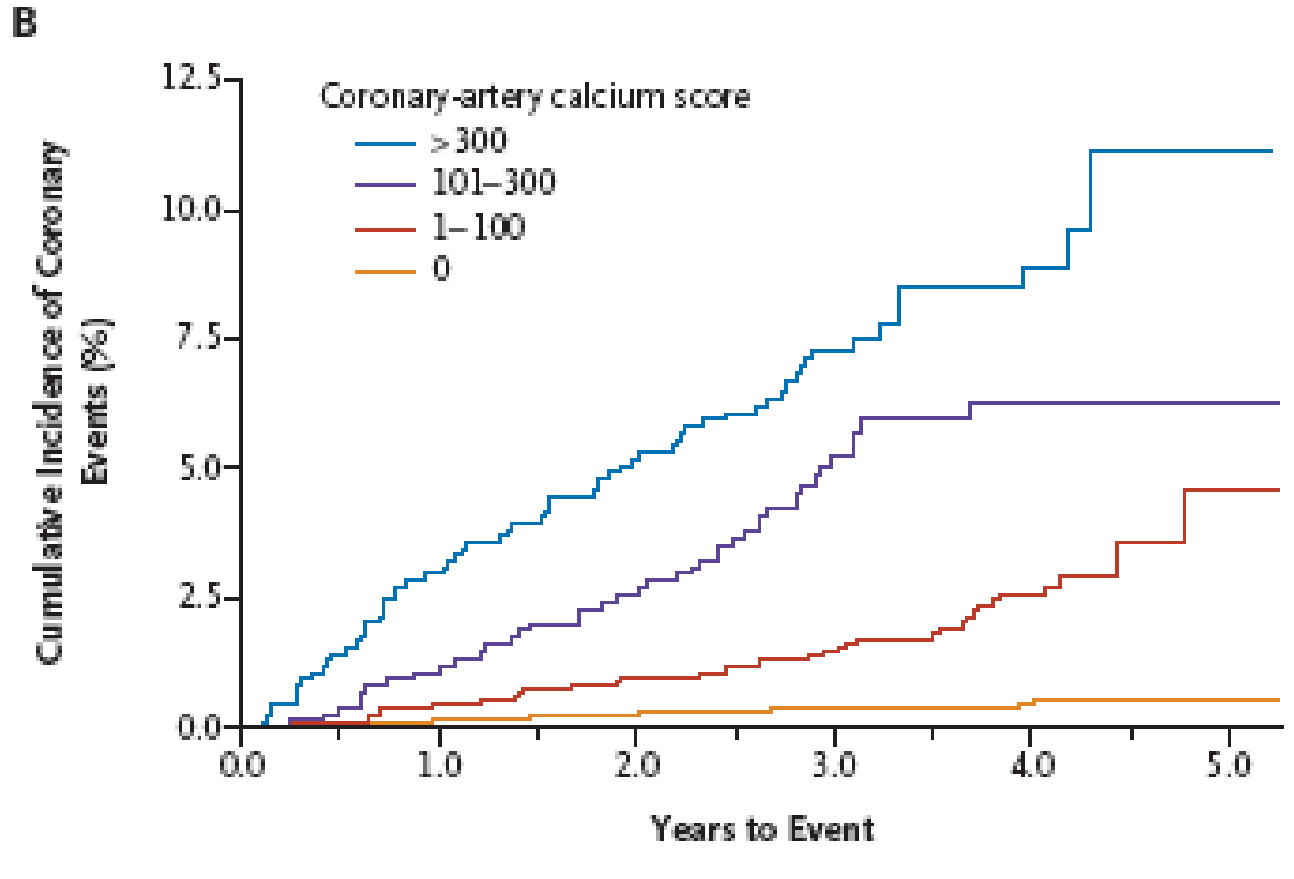
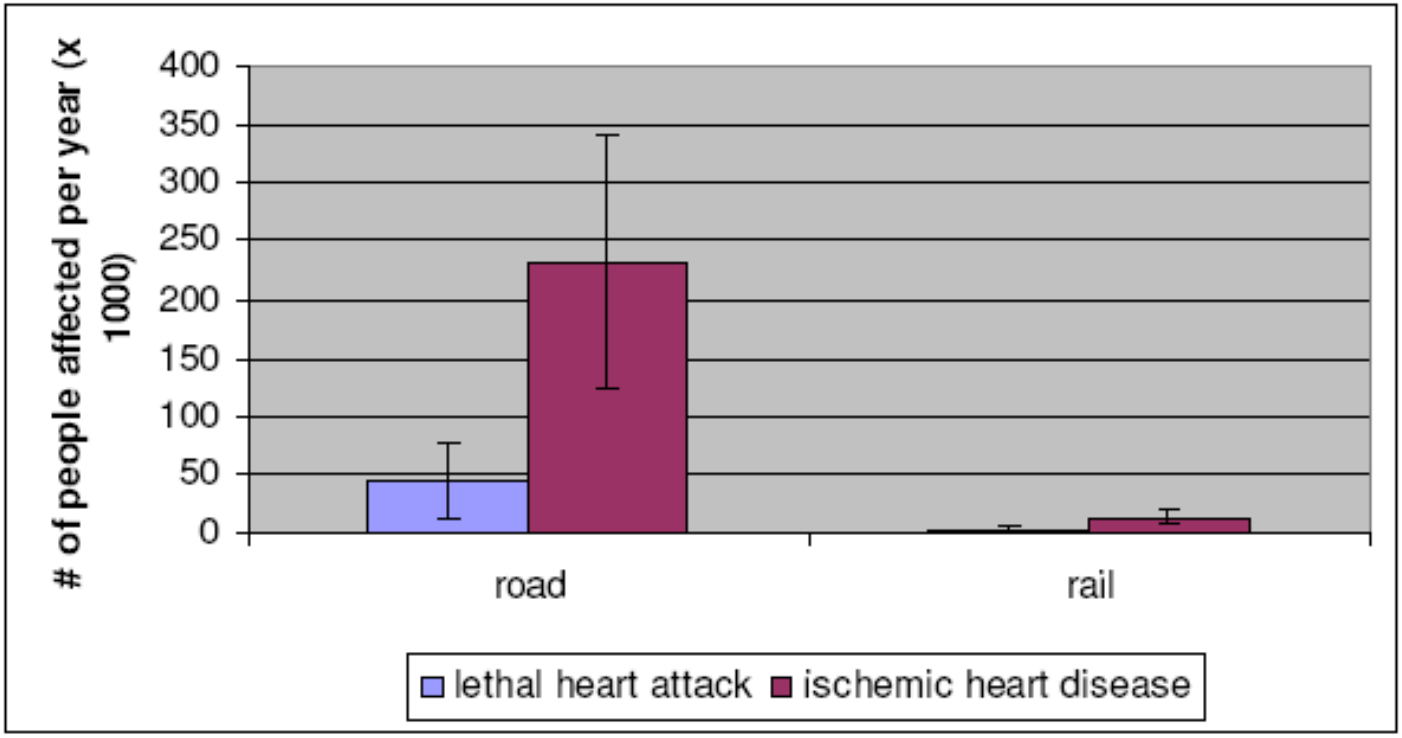


Figure 1. Unadjusted Kaplan–Meier Cumulative-Event Curves for Coronary Events among Participants with Coronary-Artery Calcium Scores of 0, 1 to 100, 101 to 300, and More Than 300.

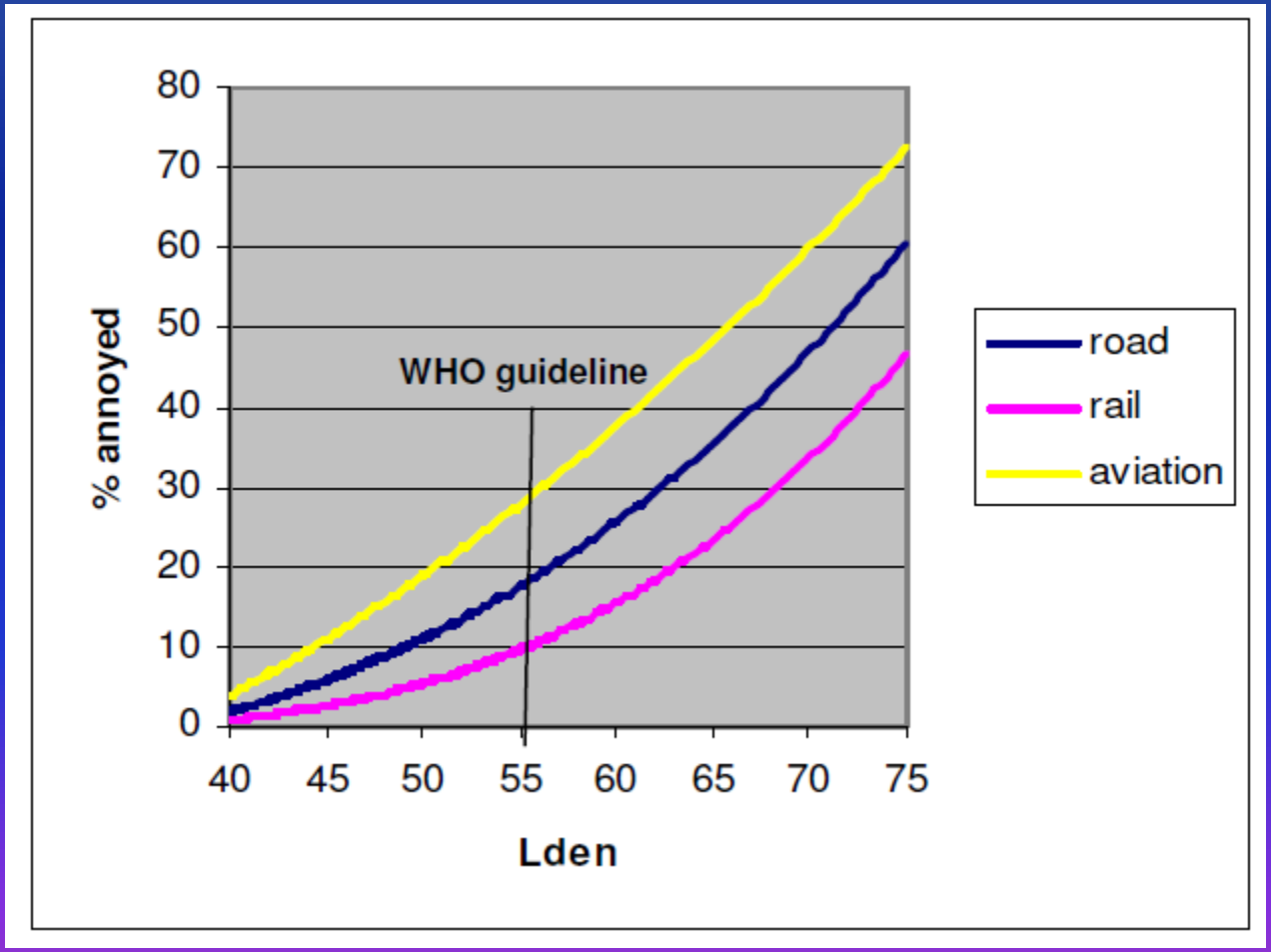
Detrano R et al NEJM 2008:358:1336-1345

Number of people developing coronary artery disease/year and lethal heart attack/year in EU due to traffic noise

Indication of number of people affected by an ischemic heart disease or suffering a lethal heart attack due to traffic noise in the EU25 (2000)



The EU dosis-effect curve for Lden versus annoyance



Miedema and Oudshoorn 2001

The EU dose response curve for aircraft noise during the day underestimates annoyance

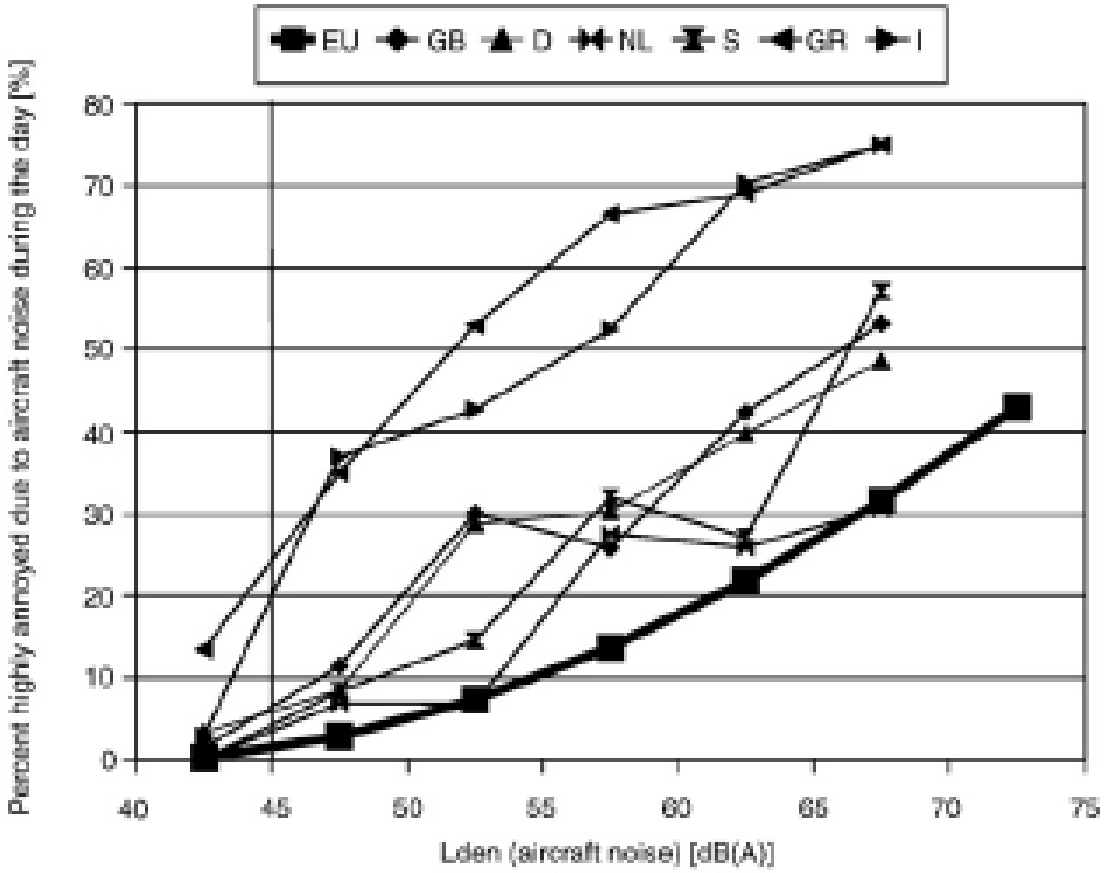


Fig. 1. Relationships between aircraft noise (L_{den}-air) and annoyance due to aircraft noise during the day (EU and country-specific curves). Note: The EU curve is defined for noise levels from 45 to 75 dB(A).

Babisch et al. Environ Int 2009 Nov;35(8):1169-76

The EU dose response curve for annoyance during the night due to aircraft noise underestimates annoyance

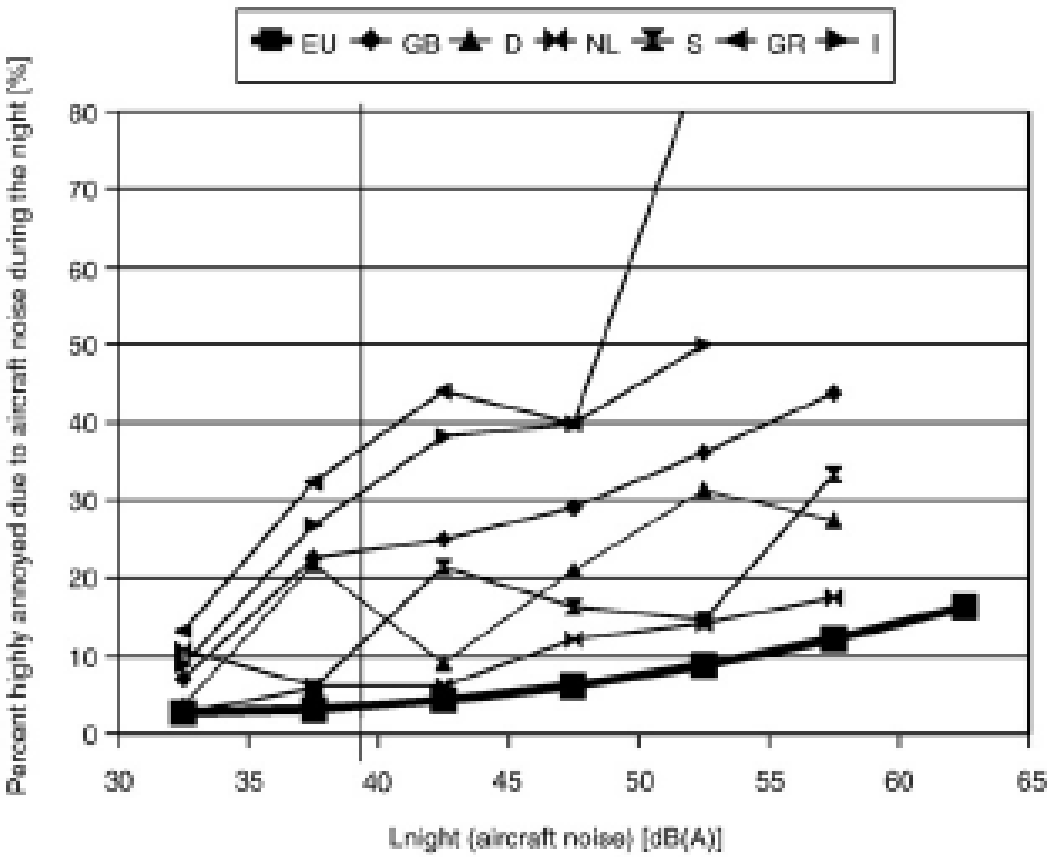


Fig. 3. Relationships between aircraft noise (L_{night}-air) and annoyance due to aircraft noise during the night (EU and country-specific curves). Note: The EU curve is defined for noise levels from 40 to 70 dB(A).

Babisch et al. Environ Int 2009 Nov;35(8):1169-76

How far reaches the environmental foot print of a highway?

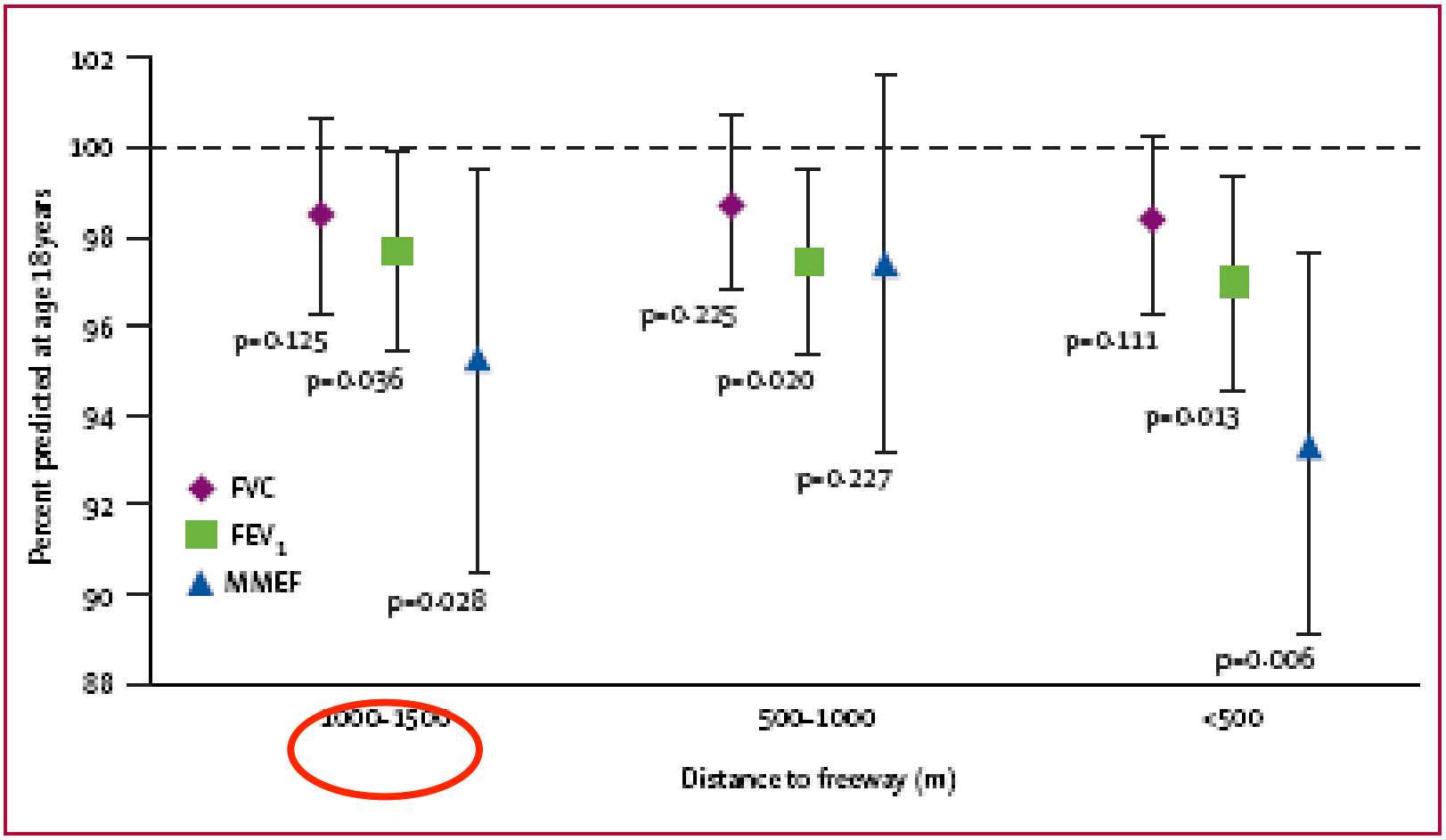


Figure: Percent-predicted lung function at age 18 years versus residential distance from a freeway
The horizontal line at 100% corresponds to the referent group, children living >1500 m from a freeway

Gaudermann et al *The Lancet* 2007; **369**:571-577

Hospital Admission of > 65 yr old in USA and Aircraft Noise

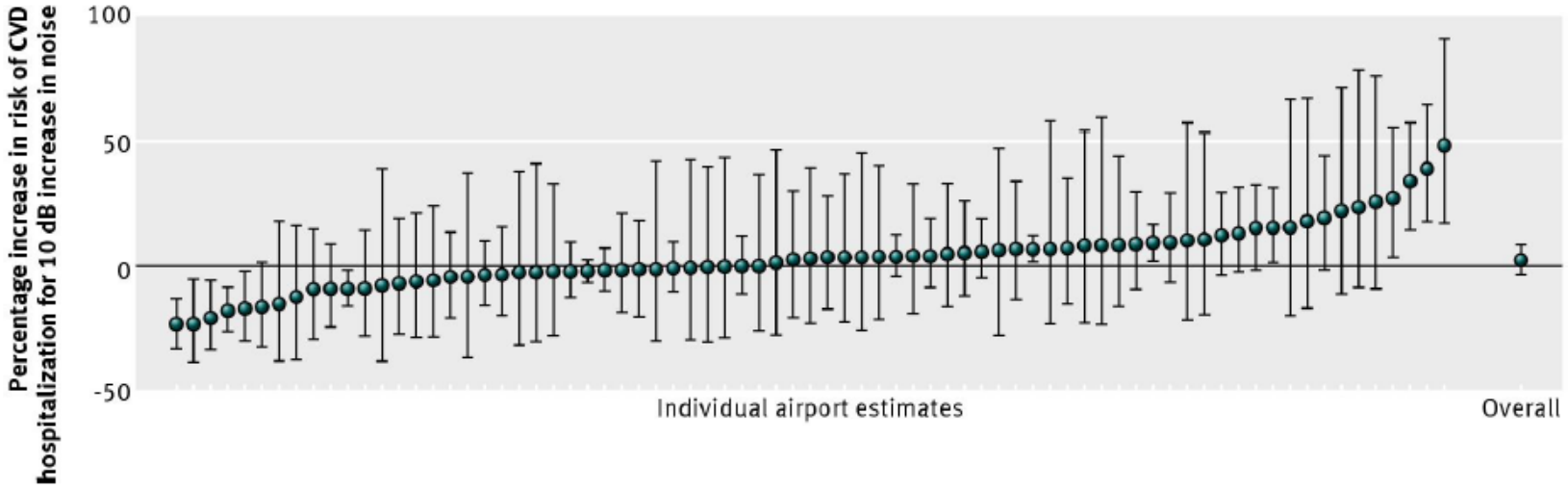
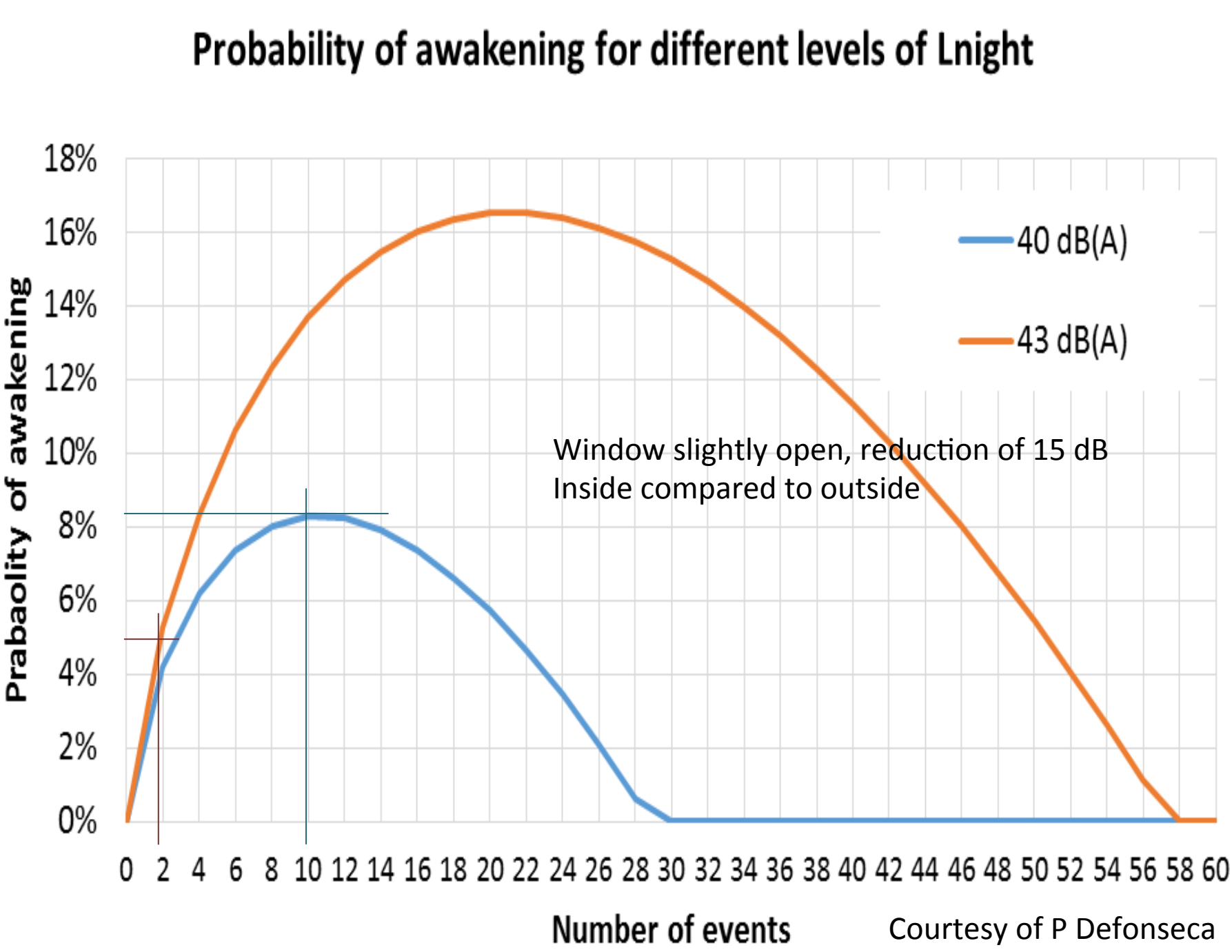


Fig 4 Airport specific and overall estimates of percentage increase in hospital admission rate for cardiovascular disease (CVD) associated with 10 dB (day-night sound level) increase in the population weighted noise exposure. This model controls for individual demographics (age, sex, and race), zip code level socioeconomic status and demographics (% Hispanic and median household income), and annual average fine particulate matter and ozone levels (model 3). Airport specific estimates are arranged from lowest to highest values

Correia AW et al *BMJ* 2013;347:f5561 doi: 10.1136/bmj.f5561



Courtesy of P Defonseca

A Prospective Study of Change in Sleep Duration: Associations with Mortality in the Whitehall II Cohort

Table 4—Mortality from Phase 3 Onwards by Change in the Number of Hours Sleep Between Phase 1 and Phase 3

Cause of death	Change in hours of sleep between Phase 1 and Phase 3			
	Increase from 5 or 6 hours[a]	Reference group (No change in hours)	Decrease from 6, 7, or 8 hours[b]	Increase from 7 or 8 hours[c]
All-causes				
Number of deaths	55		57	58
Hazard ratio (95% CI) - Age adjusted	0.88 (0.60–1.28)	1.0	1.72 (1.25–2.38)	1.84 (1.31–2.58)
Hazard ratio (95% CI) - Fully adjusted #	0.92 (0.63–1.35)	1.0	1.62 (1.17–2.25)	1.75 (1.24–2.47)
CVD				
Number of deaths	16		24	12
Hazard ratio (95% CI) - Age adjusted	0.74 (0.37–1.46)	1.0	2.39 (1.41–4.05)	1.29 (0.64–2.59)
Hazard ratio (95% CI) - Fully adjusted #	0.85 (0.42–1.70)	1.0	2.04 (1.20–3.49)	1.22 (0.60–2.48)
Non-CVD				
Number of deaths	38		33	45
Hazard ratio (95% CI) - Age adjusted	0.97 (0.61–1.54)	1.0	1.48 (0.98–2.23)	2.09 (1.40–3.12)
Hazard ratio (95% CI) - Fully adjusted #	0.98 (0.62–1.57)	1.0	1.44 (0.95–2.18)	2.06 (1.38–3.08)

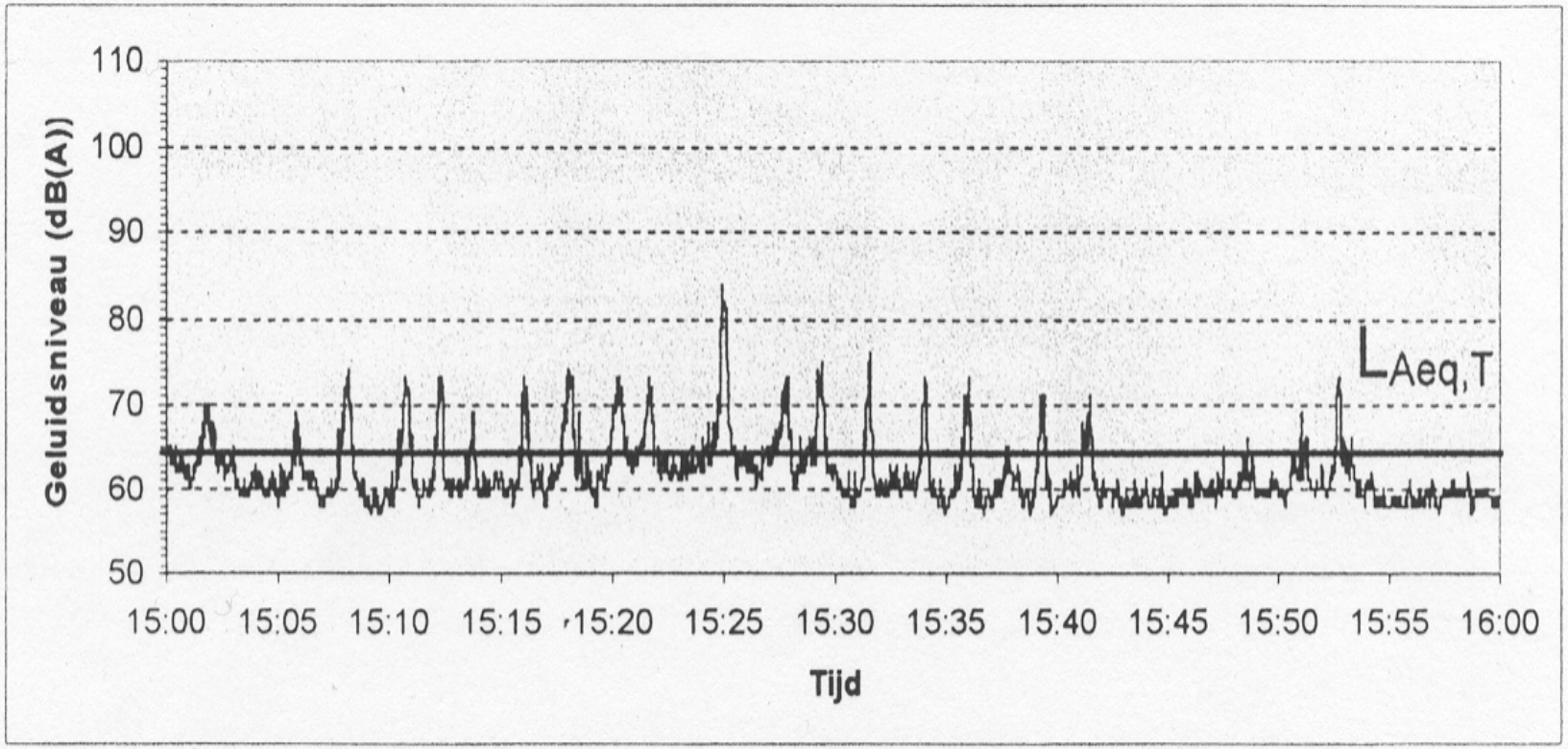
Fully adjusted hazard ratios are adjusted for the following Phase 3 measures:- age, sex, marital status, employment grade, smoking status, physical activity, alcohol consumption, self-rated health, body mass index, systolic blood pressure, cholesterol, physical illness, modified GHQ score, prevalent CHD

[a] 5 or□

[b] □ 11 deaths)

[c] 7 or 8 hours sleep at Phase 1 and >7 or 8 hours, respectively, at Phase 3; reference is either 7 or 8 hours at both phases (76 deaths)

What is an A weighted equivalent sound exposure level $L_{Aeq,T}$?

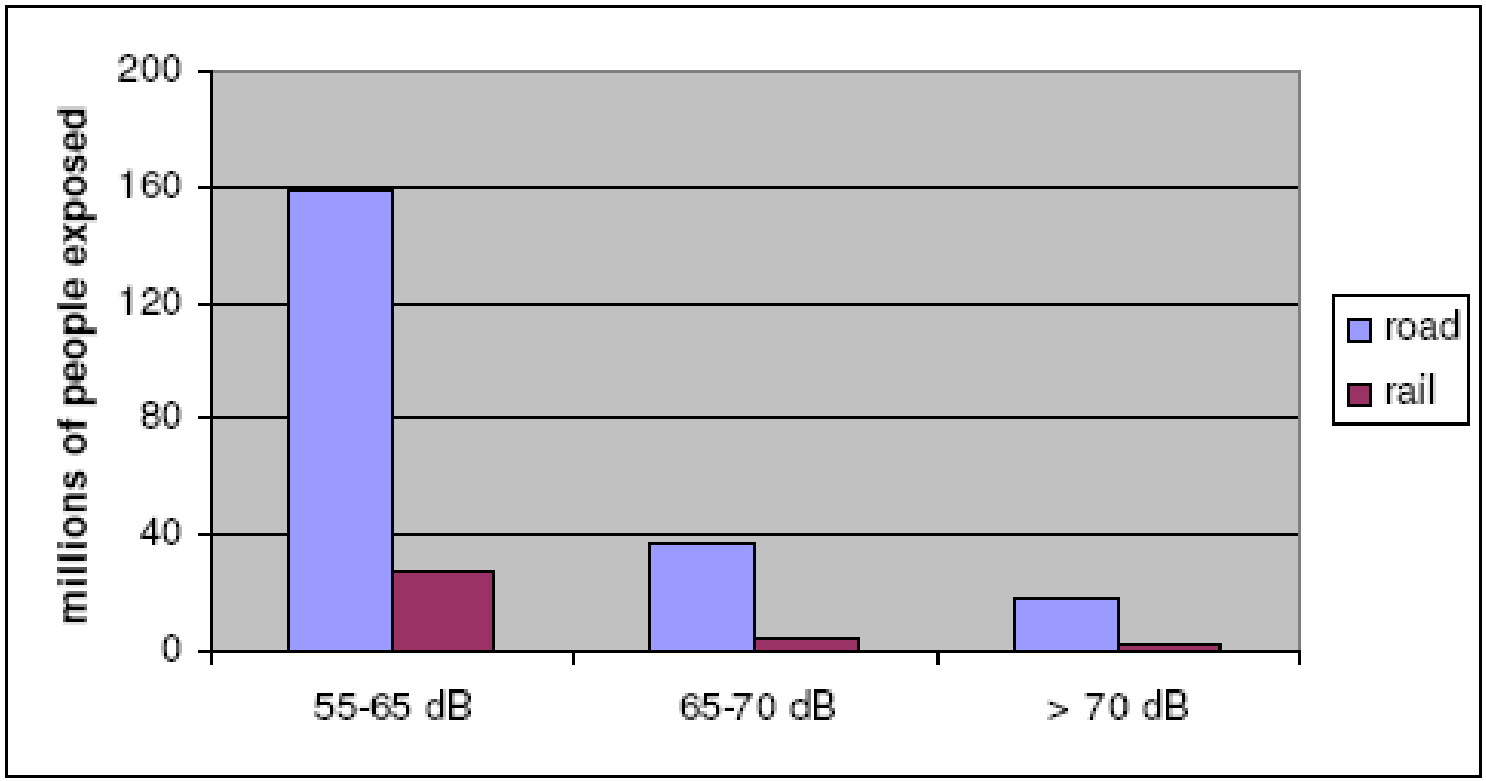


Figuur 1 *Voorstelling van het A-gewogen equivalente geluidsdrukniveau ($L_{Aeq,T}$)*

Serruys P et al. Geluidscontouren rond de luchthaven Brussel-Nationaal 2001

Number of people exposed to harmful level of noise in EU

Number of people exposed to road and rail traffic noise in 25 EU countries in 2000



Note: This figure covers the EU27 except Cyprus and Malta.
Source: INFRAS/IWW (2004), OECD/INFRAS/Herry (2002), calculations by CE Delft (for Estionia, Latvia, Lithuania).

Den Boer LC en Schroten A: Traffic Noise Reduction in Europe: CE Delft 2007

GUIDELINES FOR COMMUNITY NOISE

Edited by

Birgitta Berglund
Thomas Lindvall
Dietrich H Schwela

This WHO document on the *Guidelines for Community Noise* is the outcome of the WHO-expert task force meeting held in London, United Kingdom, in April 1999. It bases on the document entitled "Community Noise" that was prepared for the World Health Organization and published in 1995 by the Stockholm University and Karolinska Institute.

Cardiovascular Risk and Aircraft Noise (Men > 40 yr)

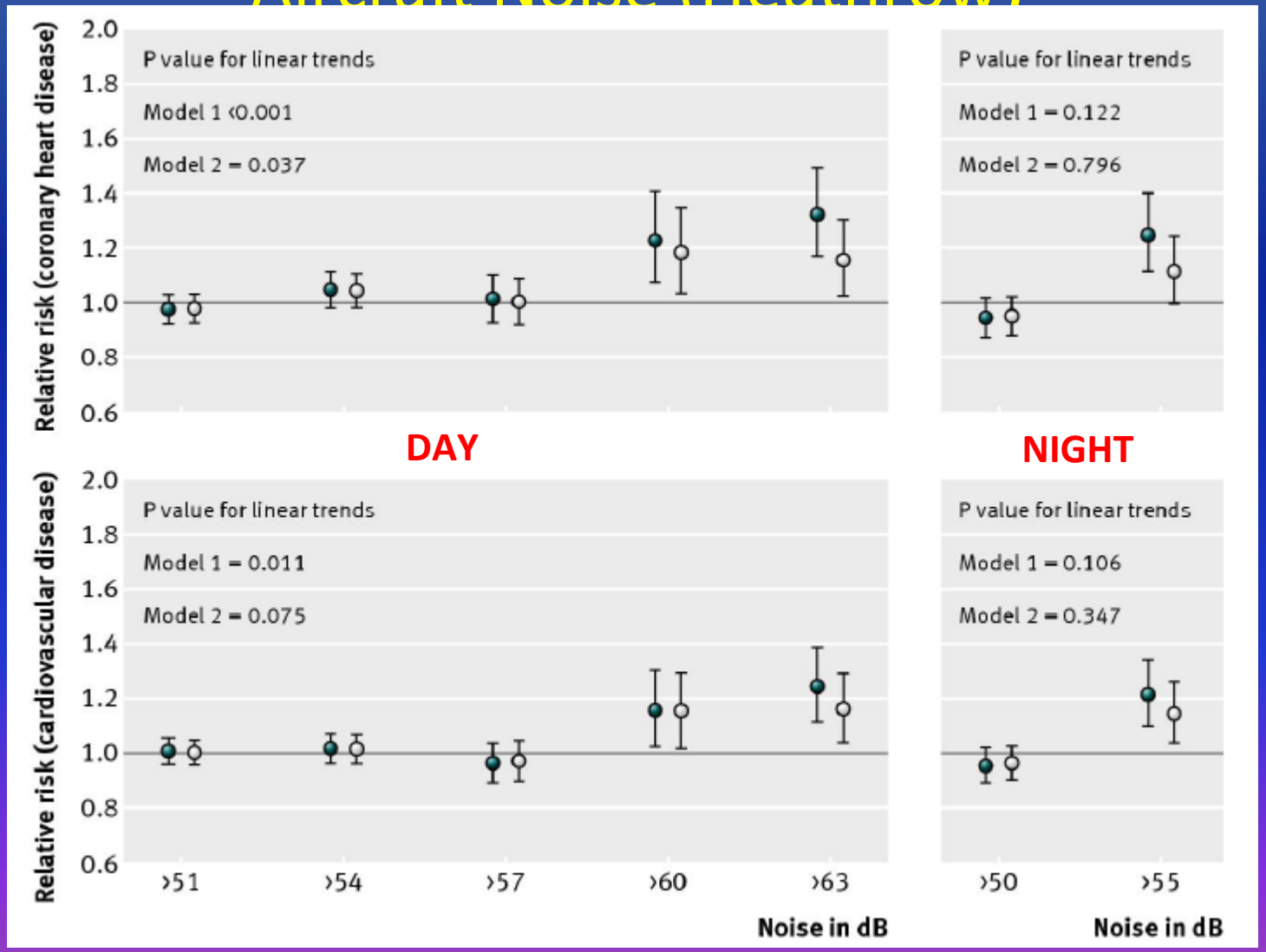
DISEASE/MEN	LAeq Day > 60dbA	Lnight > 55dB
CARDIOVASCULAR DISEASES	+ 69%	+ 42%
STROKE	n.s.	+ 66%
CORONARY ARTERY DISEASE (STABLE)	+ 61%	+ 37%

OR to develop CV disease:
1.044 (CI 1.018-1.071) / 1 dB > 40 Lnight)

Cologne Bonn Airport Noise Study

http://www.umweltdaten.de/publikationen/fpdf-l/3774.pdf

Risk of coronary artery disease/CV disease and Aircraft Noise (Heathrow)



Hansell et al *BMJ* 2013;347:f5432 doi: 10.1136/bmj.f5432

Influence of sound insulation (with air conditioning) on annoyance (Okinawa)

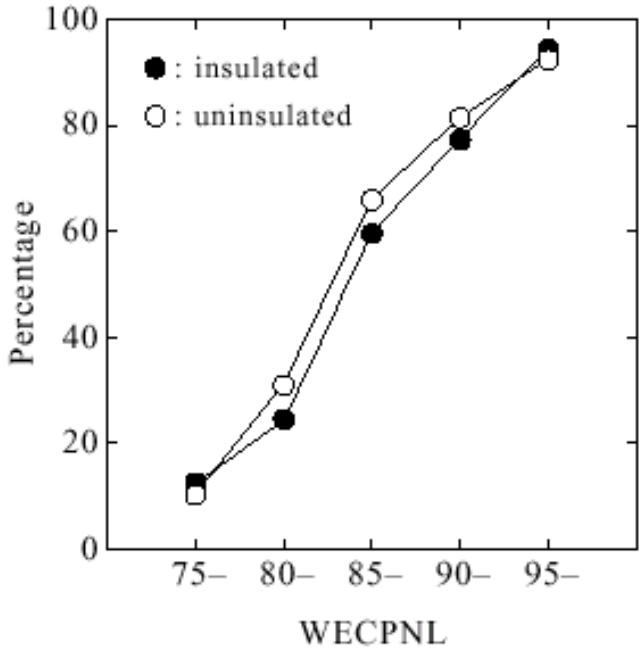


Figure 4.4 Percentage of the response on the annoyance *vs.* WECPNL in relation to sound insulation.

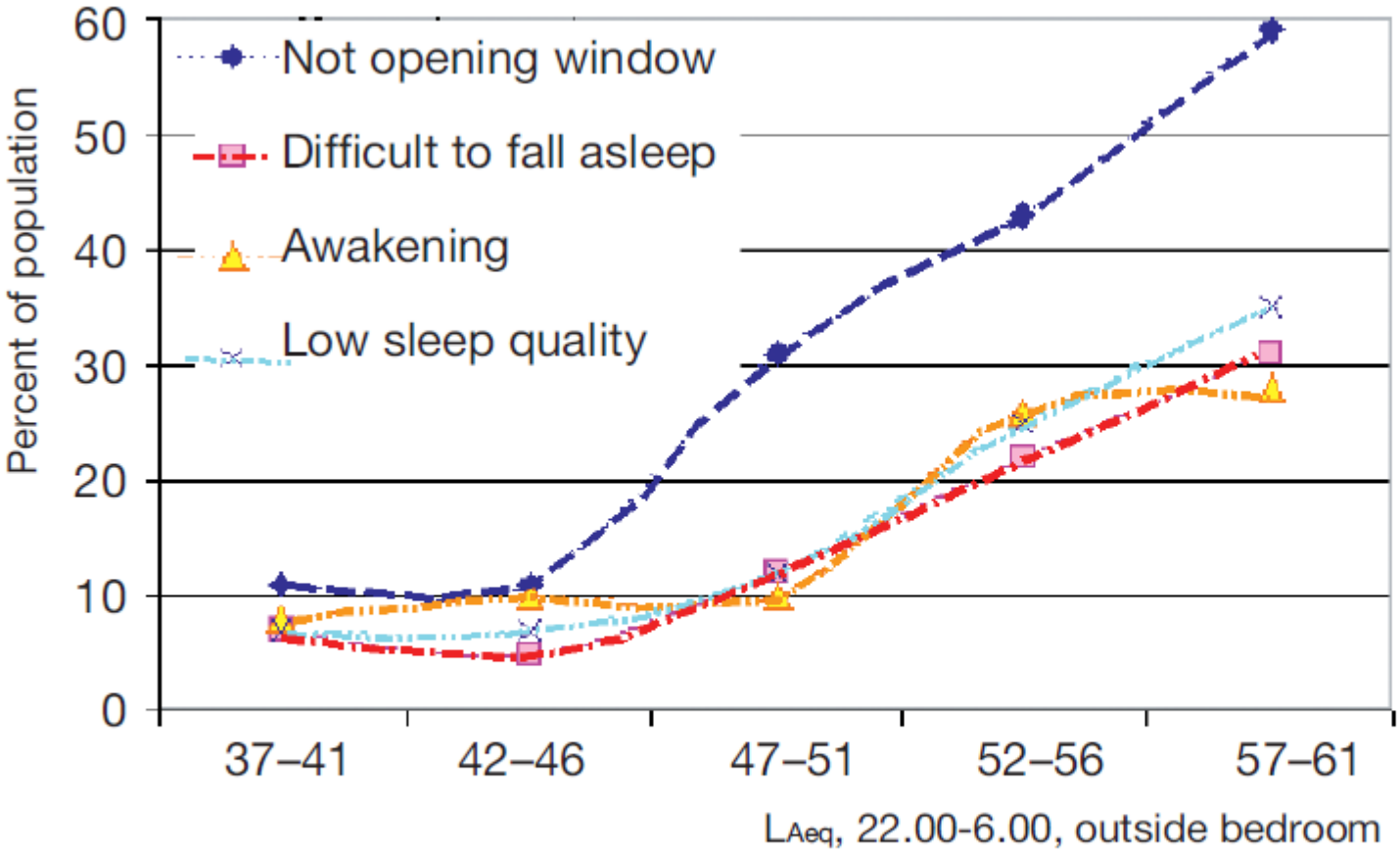
Category: "1. Very annoying." "2. Pretty annoying."

WHO Guidelines 1999

- *'For a good sleep, it is believed that indoor sound pressure levels should not exceed approximatelly 45 dB LAmax more than 10-15 times per night…*
- *Ten to 15 of these events during an eight-hour night-time implies an LAeq,8h inside of 20-25 dB*
- *This is 5-10 dB below the LAeq,8h of 30 dB for continuous night-time noise exposure*
- *.. And shows that the intermittent character of noise has to be taken into account when setting limits for noise exposure…*
- *This can be achieved by considering the number of noise events and the difference between maximum sound pressure level and the background level of these events..'*

WHO Guidelines for community noise (1999) p 26

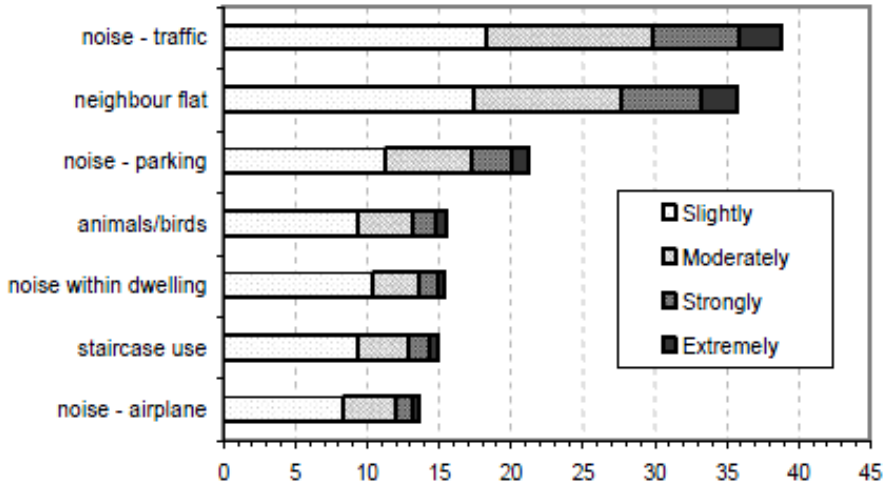
Swedish soundscape research on road traffic noise



Source: Öhrström, in European Commission, 2002a.

WHO night time noise guideline 2009

Sources of noises that bother or annoy adults (N=7949)



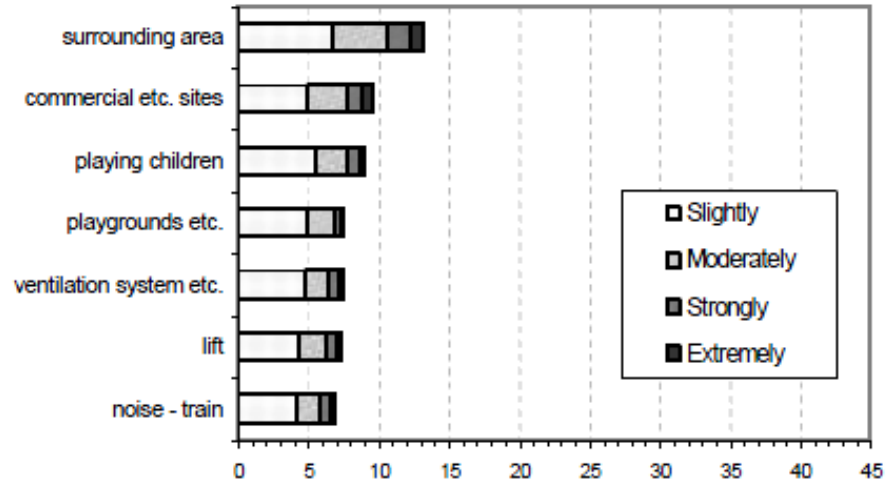
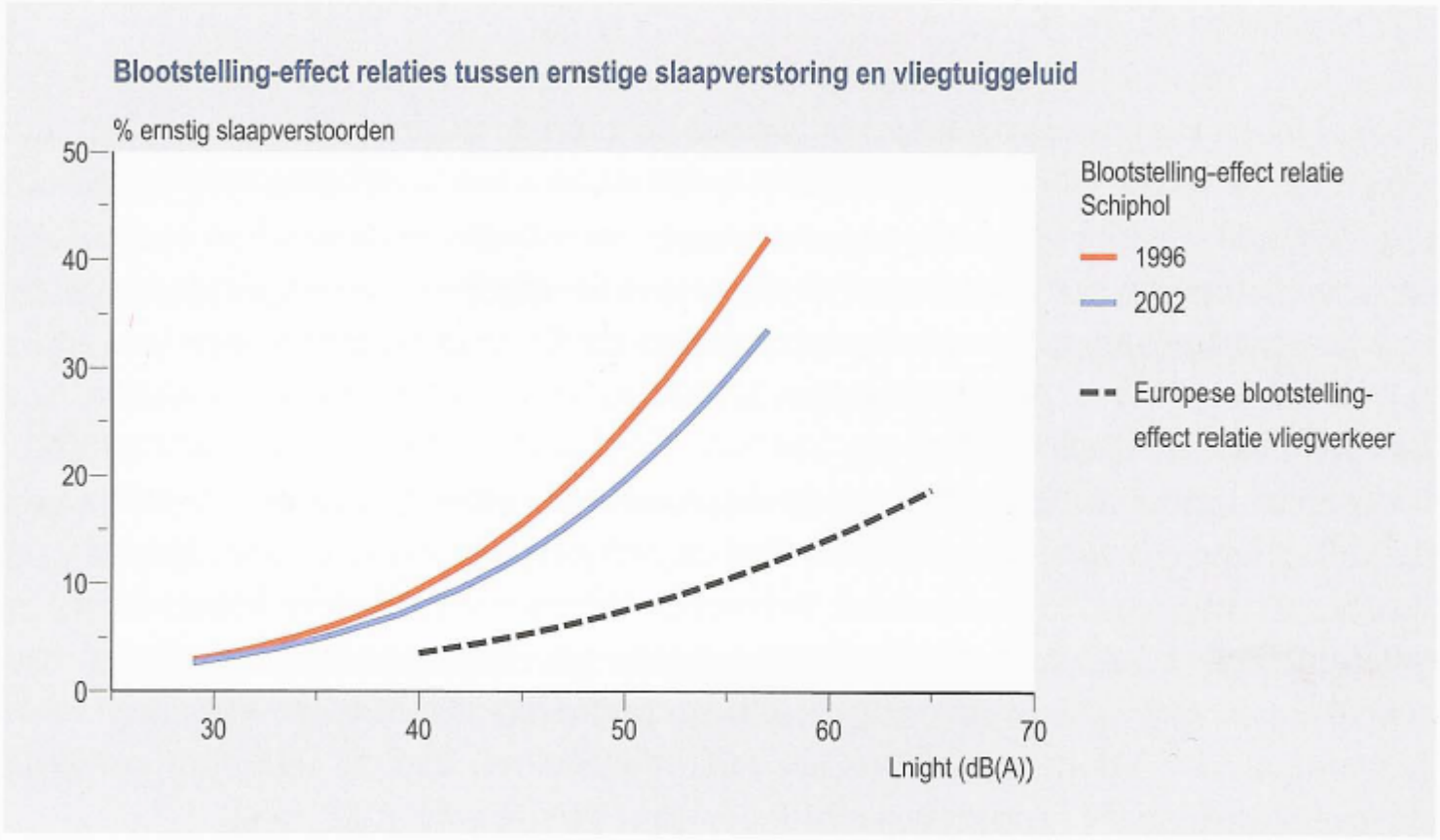


Figure 1: Percentage frequency of different sources which bothers or annoys adults, children and elderly (in 4 scales: slightly, moderately, strongly, extremely) N = 7949

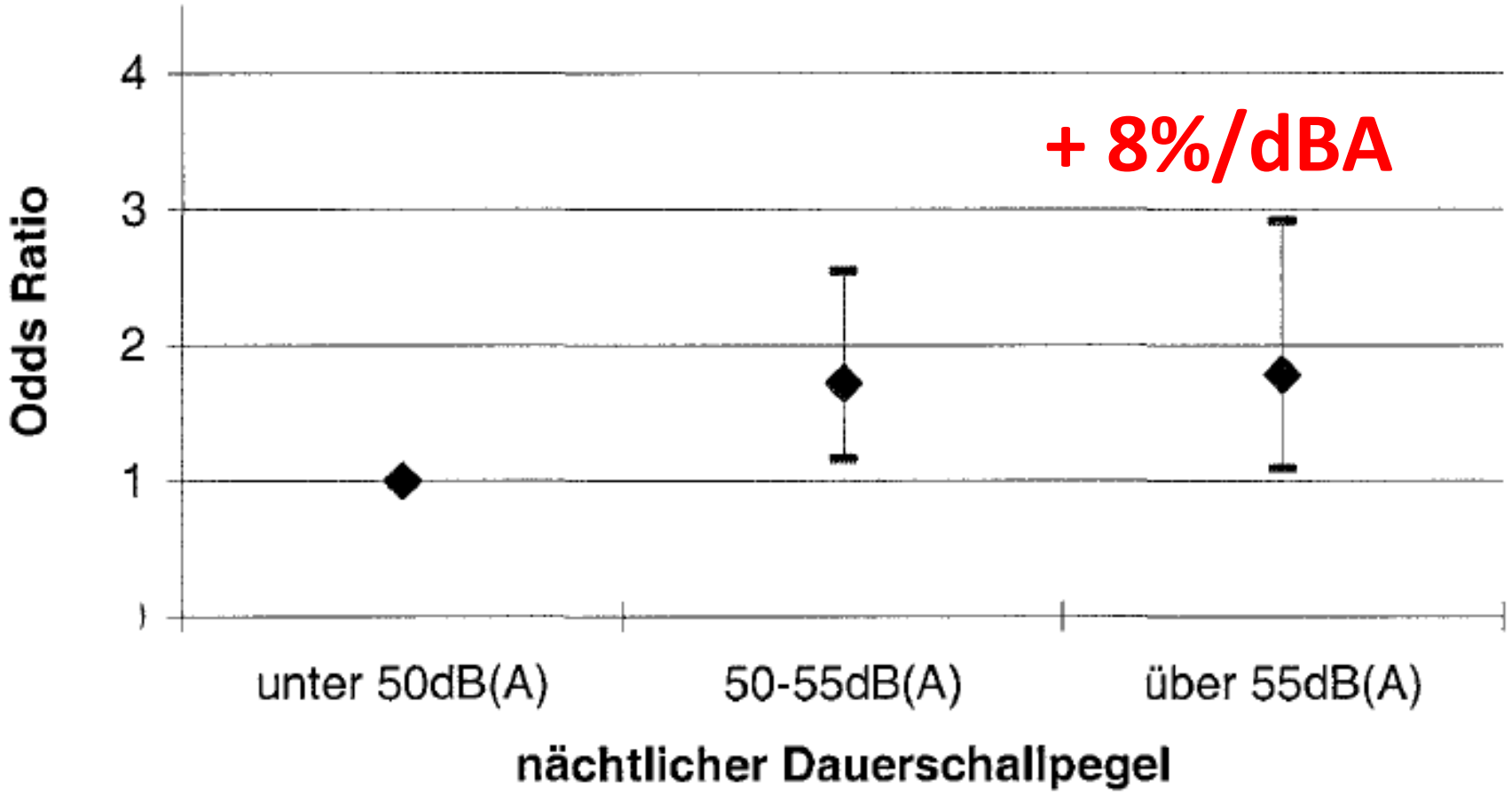
Large **A**nalysis and **R**eview of **E**uropean housing and health **S**tatus (**LARES**) WHO 2004,

Is the EU noise exposure response curve for sleep disturbance still valid?



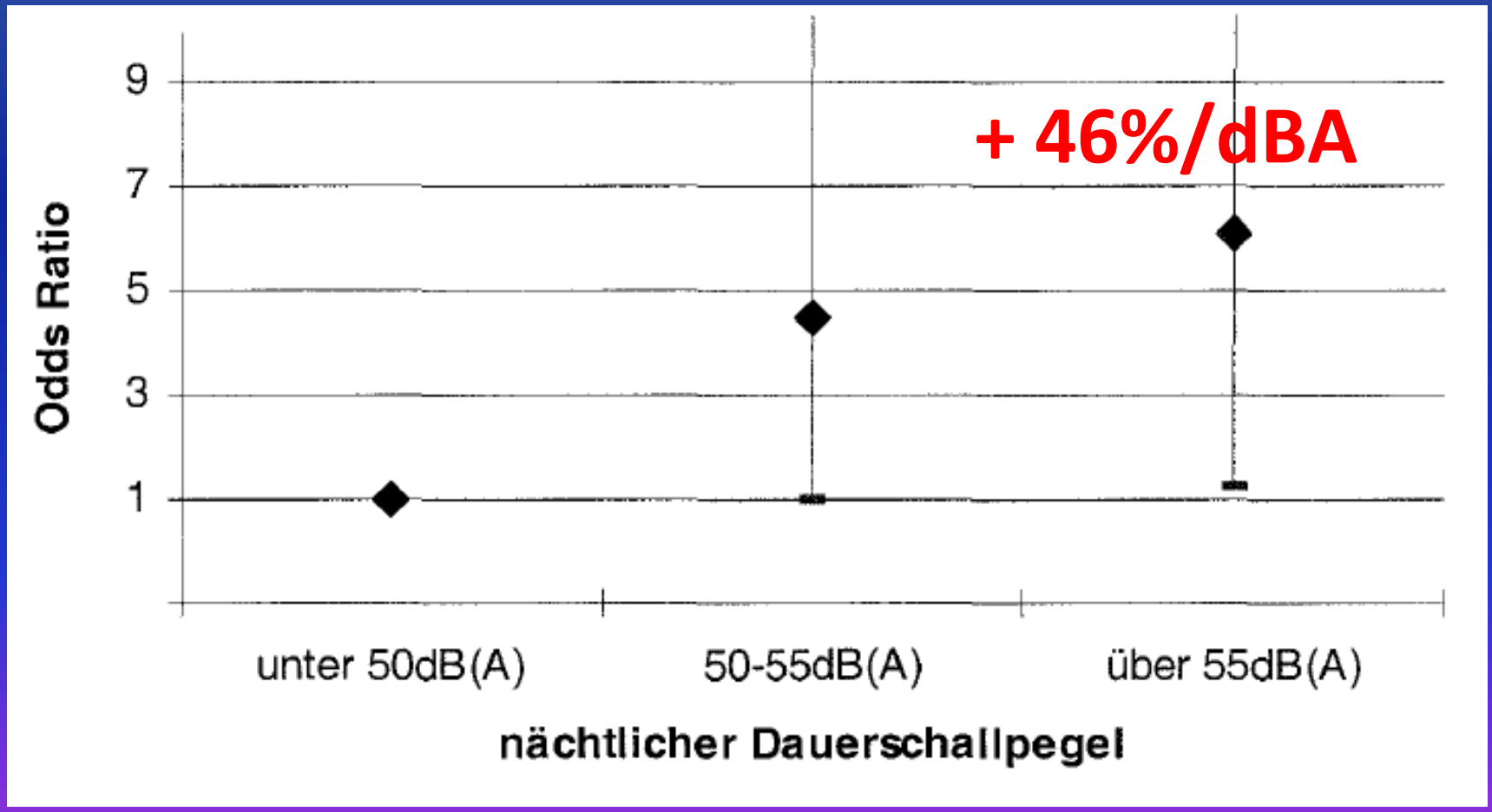
Figuur B.2.5 Blootstelling-effect relaties tussen zelfgerapporteerde ernstige slaapverstoring en vliegtuiggeluid (Lnight) berekend uit de enquêtes van de Gezondheidskundige Evaluatie Schiphol, die zijn uitgevoerd in 1996 en in 2002 en volgens Miedema et al. (2004) voor de EU.

Night-time traffic noise in Berlin and life time risk of hypertension (all)



SGS: Maschke et al, 2003, Forschungsbericht 298 62 515 UBA-FB 000387

Night-time traffic noise and life time risk of hypertension (open window)

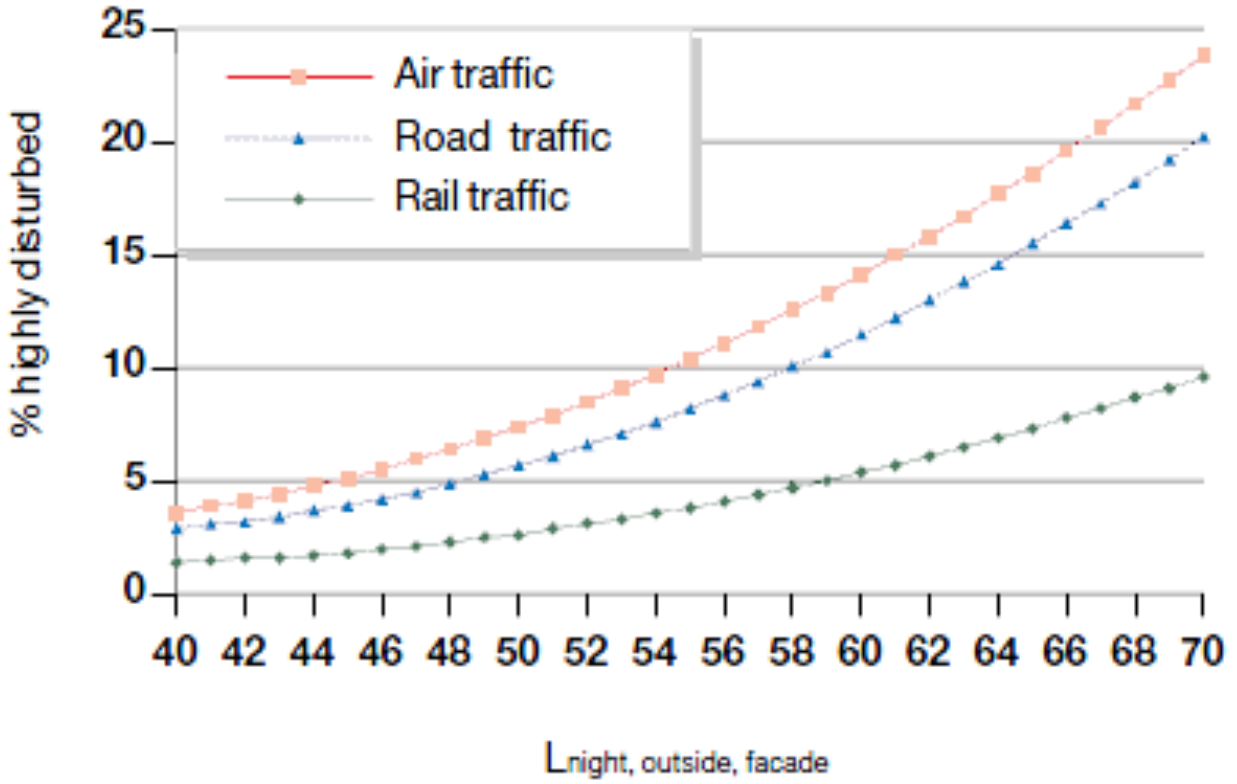


SGS : Maschke et el, 2003 Forschungsbericht 298 62 515 UBA-FB 000387

EU noise exposure- response for high sleep disturbance (Lnight)

Fig. 4.1
High sleep disturbance by noise at night

Source:
European Commission, 2004.



Night noise guidelines for Europe WHO 2009 p 58

Percentage of population **highly disturbed by noise during sleep** in Netherlands

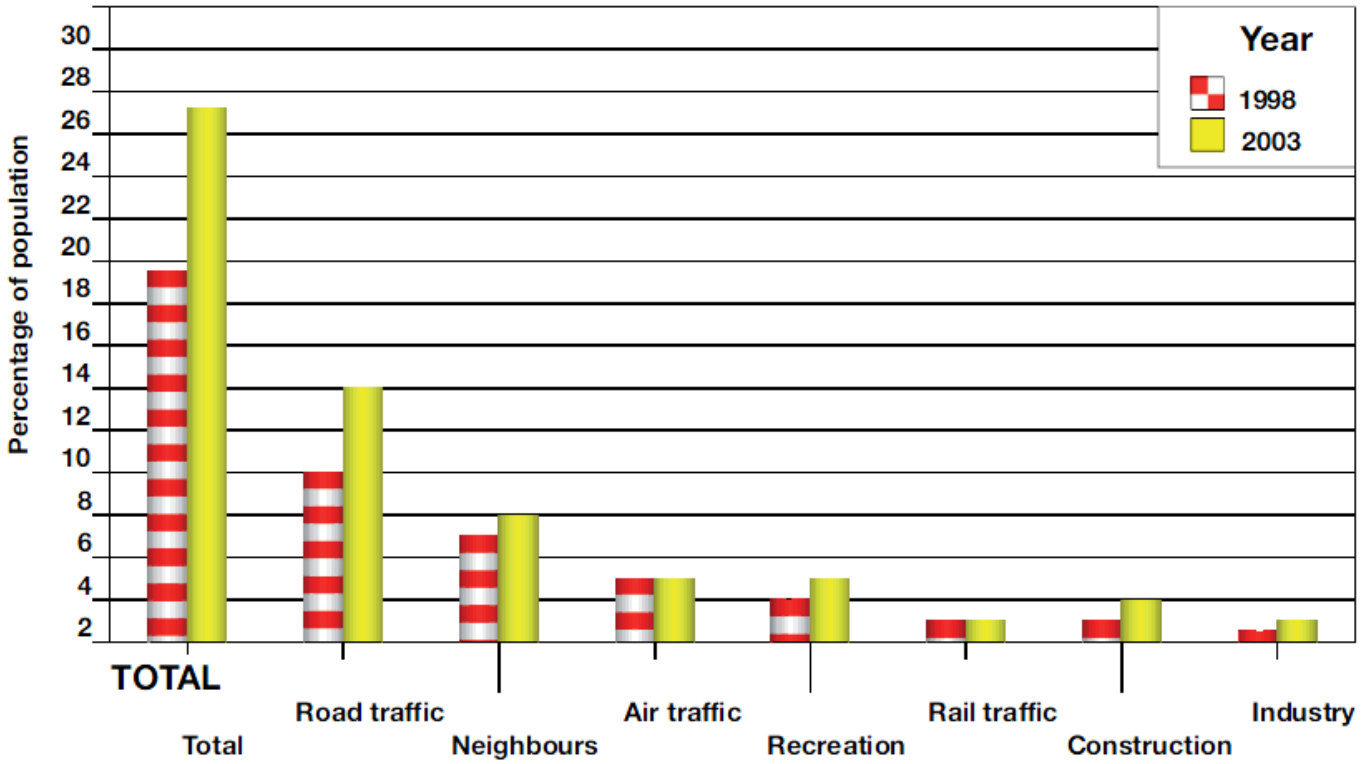


Fig. 1. Percentage of population highly disturbed by noise during sleep in the Netherlands: survey results for 1998 and 2003

WHO Night time noise guidelines 2009