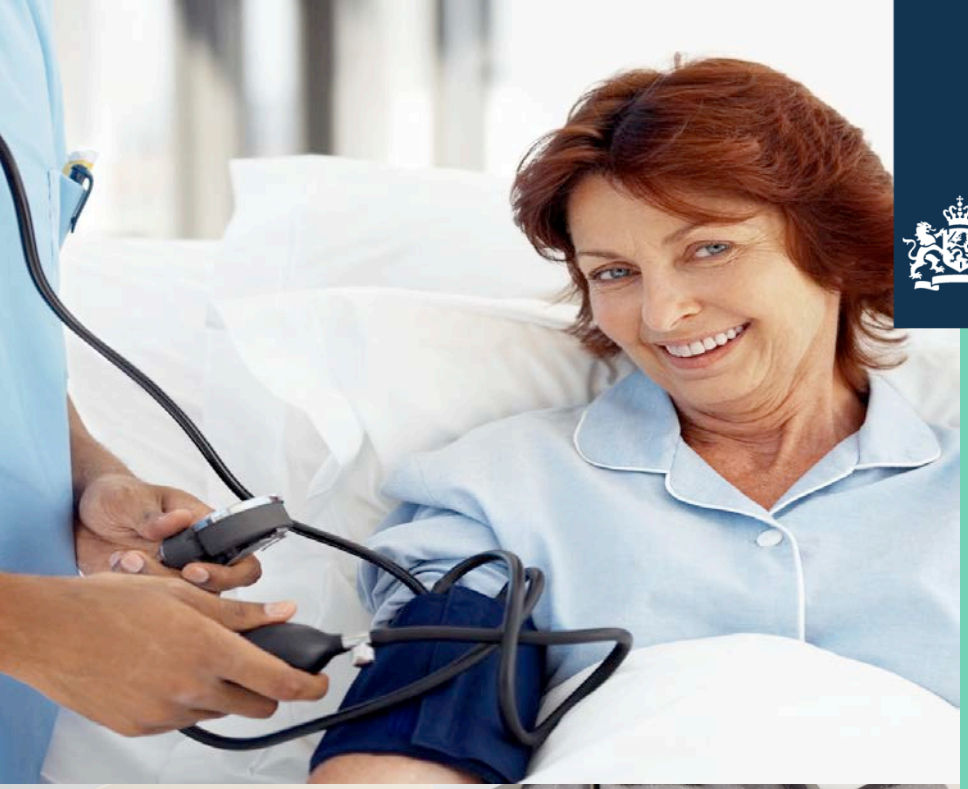


National Institute for Public Health
and the Environment
Ministry of Health, Welfare and Sport

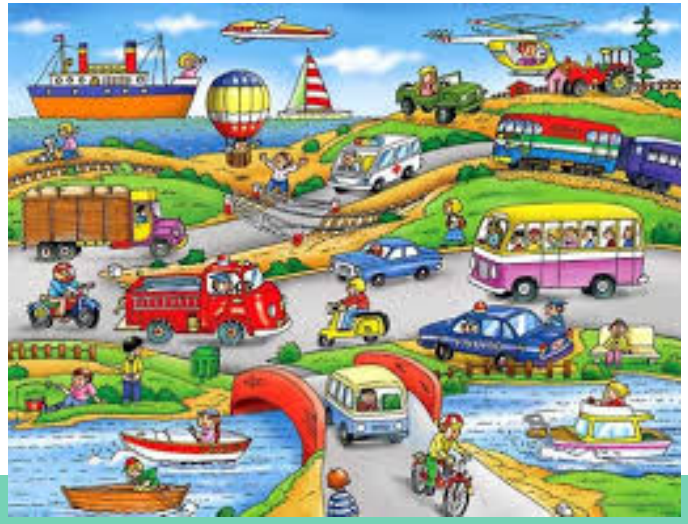
Noise and blood pressure: the NORAH Blood Pressure Study in broader context

Elise van Kempen

ICANA Health, 2015| 12 November 2015

Transportation noise

- Essential component of modern life
- Most human transportation activities generate sounds
- Transportation is the most important source of community noise in Europe
- A large part of the population is exposed to different sources of transportation noise
- Noise is also one of the environmental stressors purported to have adverse effects on health and well-being



Exposure to noise in Europe

Table. The number of residents with an exposure equal to or above 55 dB L_{den} or equal to or above 50 dB L_{night} of the second round of noise Mapping (EEA33). Source: Houthuijs et al., 2014

Noise source	# residents ≥ 55 L_{den}	# residents ≥ 50 L_{night}
Aircraft noise in agglomerations*	1,700,000	470,000
Aircraft noise outside agglomerations related to major airports	660,000	170,000
Road traffic noise in agglomerations*	42,000,000	29,600,000
Noise from major roads outside agglomerations	28,100,000	17,700,000
Railway noise in agglomerations*	3,900,000	2,900,000
Noise from major railways outside agglomerations	3,500,000	2,000,000

* Including major sources/airports

Noise and cardiovascular disease in health guidelines (I)

- **International Commitee Dutch Health Council (1994):** "There was sufficient evidence for an association between environmental noise exposure and hypertension and ischemic heart disease.
- The observed threshold for hypertension was estimated to correspond to an L_{dn} value of 70 dB for outdoor environmental noise exposure. The same was suggested for ischemic heart disease."

- **WHO (2000):** "Epidemiological studies show that cardiovascular effects occur after long-term exposure to noise with $L_{Aeq24hr}$ values of 65-70 dB.
- However, the associations are weak. The association is somewhat stronger for ischemic heart disease than for hypertension"

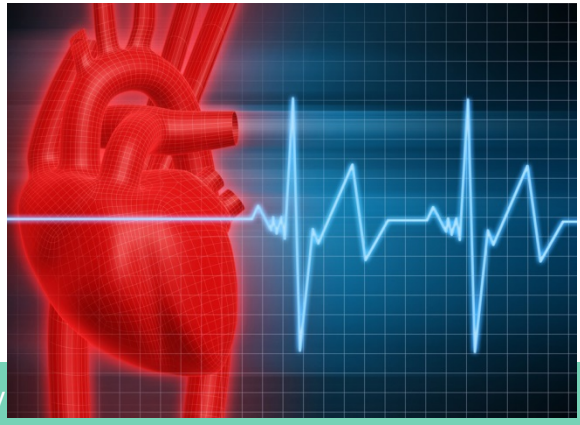
- **EEA, Good Practice Guide (2010):**For hypertension the level above which effects start to occur or start to rise above background was 50 dB (L_{den}); for ischemic heart disease this level was 60 dB (L_{den}).

Noise and cardiovascular disease in health guidelines (II)

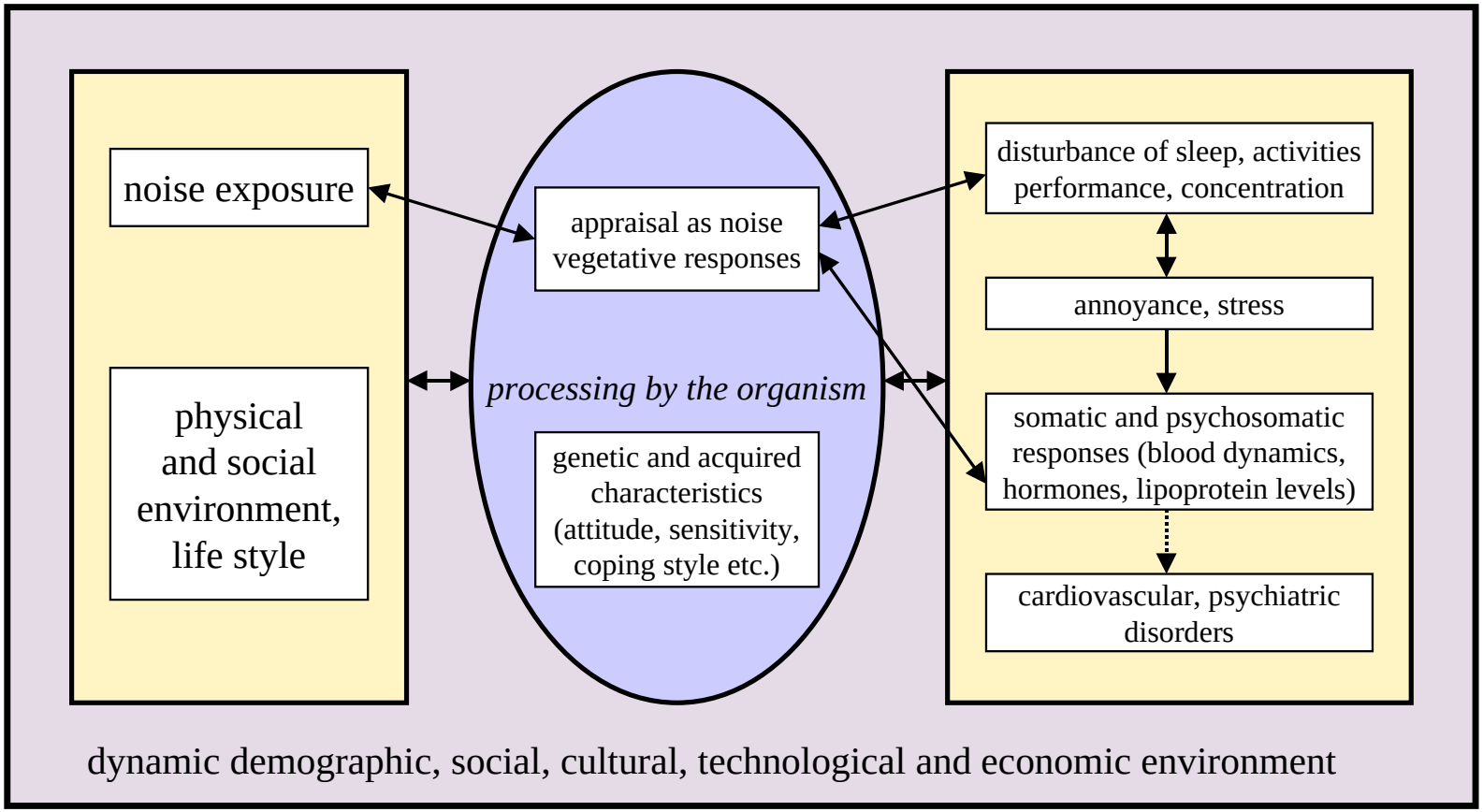
- **Dutch Health Council (2004):** "There is limited, indirect evidence of a causal relationship between exposure to night-time noise and high blood pressure and cardiac disease"

- **WHO Night noise guidelines (2009):** "There is limited evidence that *night* noise is related to hypertension and myocardial infarction; although the studies were few or not conclusive, a biological pathway could be constructed from the evidence"
- The guidelines recommend a general threshold of 55 dB for protection of cardiovascular disease

- At this moment new guidelines are being developed by WHO



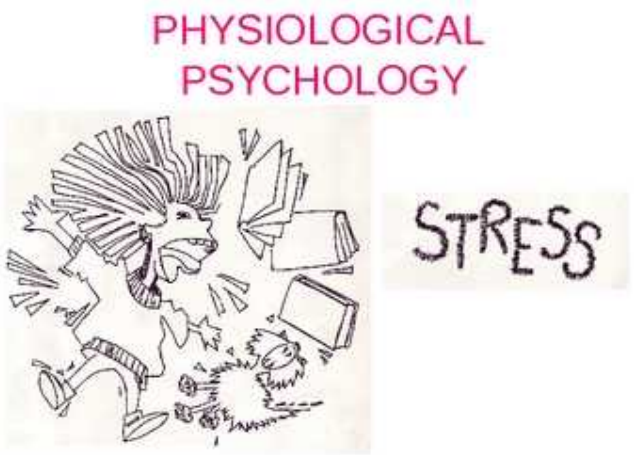
The impact of noise on the cardiovascular system



Stress…

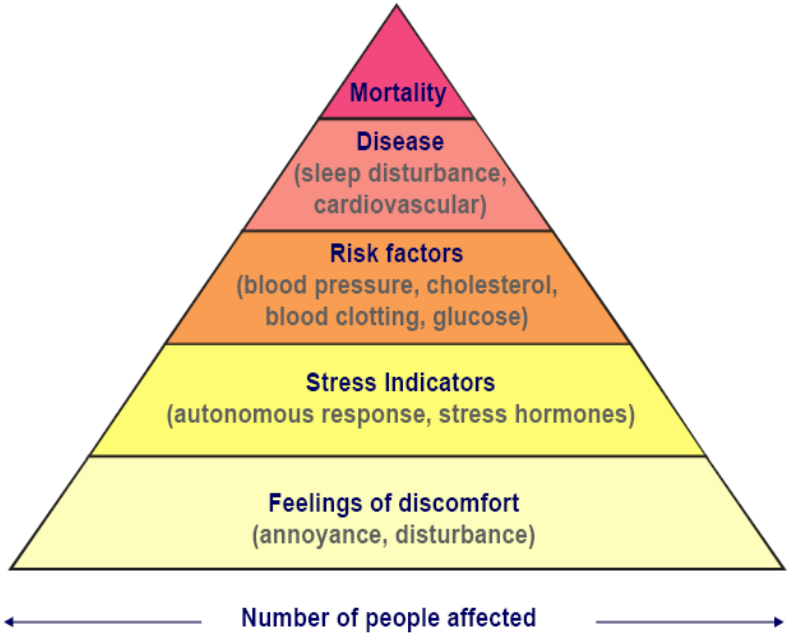
- Can have direct impacts on health
- Can manifest itself in behaviour and thus indirectly contributes to health problems

- The health of people already suffering from CVD, may deteriorate through noise exposure.
- (Clinical) disorders may (earlier) become manifest



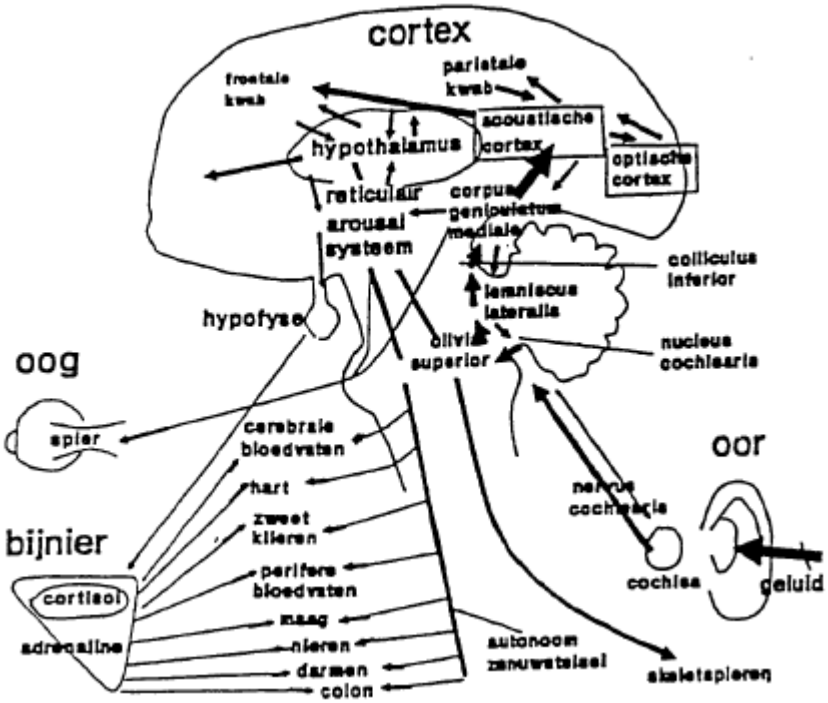
Physiological stress

- These are physiological and biochemical reactions which occur acutely
- If these last long enough, they become risk factors for CVD
- Experimental studies investigating the effects of short-term noise exposure, have found acute biochemical, physiological and cardiovascular changes, marking a common physiological stress reaction
- This occurs after activating the autonomous nervous and hormone system



Source: Babisch, 2002 (WHO 1992 - modified)

- Alternatively: assumption that the effect of noise on the auditory system is transmitted to the Reticular Arousal System (RAS) and hypothalamus, where both neuronal and hormonal systems may be activated



Stress-situation

- Stress-situation can cause several effects: e.g. the body secrets adrenal medullary hormones (e.g. noradrenaline) raising the peripheral resistance and increase of blood pressure, and heart rate

Psychological stress

- Of importance how a person perceives and appraises the different sounds in his/her daily environment
- Appraisal: “a process that determines whether or not sounds, that are present in our environment, are regarded as being noisy”
- It is suggested that the appraisal is one of the essential factors predicting short- and long term health effects of exposure to repetitive daily chronic stressors such as noise
- An indicator that is often used to operationalize appraisal of noise is annoyance

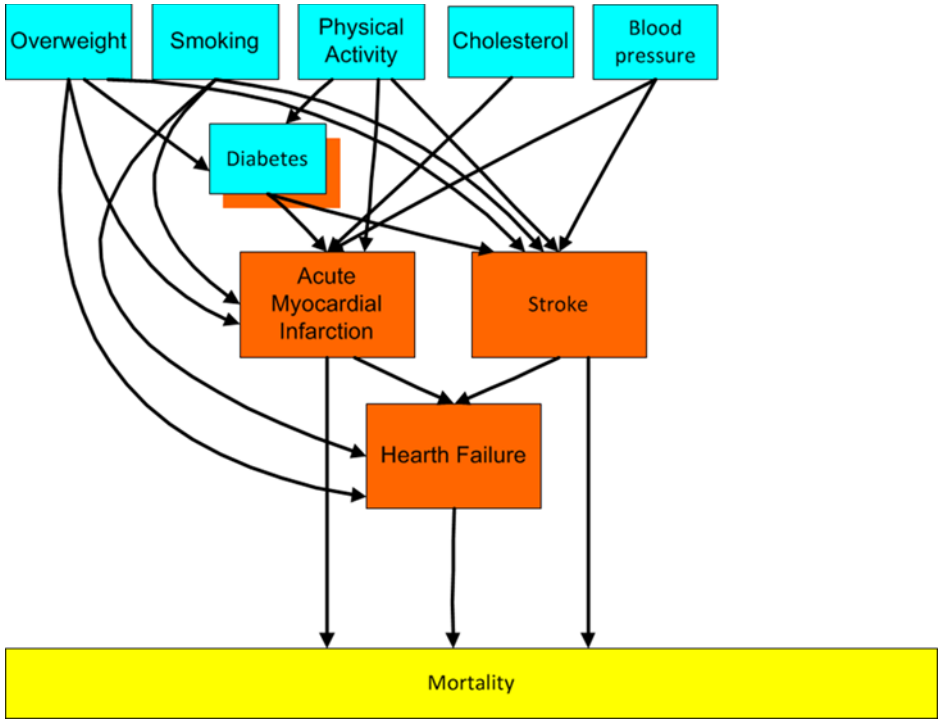
Other mechanisms

- Cardiovascular effects may also be the consequence of a decrease in sleep quality, caused by night-time noise exposure
- Chronic nighttime noise exposure might disturb the secretion of hormones such as cortisol

- People living in a city close to roads are also exposed to traffic-related air pollution.
- Indications that exposure to air pollution may affect the cardiovascular system as well
- Both noise and air pollution share the same source, so the effects could be attributed to both exposures.

Increased blood pressure and cardiovascular disease

- Most research focussed on hypertension, blood pressure and IHD
- Good evidence that hypertension is not only a risk factor for IHD but also for other CVD-endpoints: stroke, heart faillure
- If a part of the people suffering from hypertension due to noise, will develop a stroke, we should be able to find this effect in a study investigating the impact of noise on stroke



Studies investigating the impact on blood pressure

Effect	Population where effect is measured	Devices used	Data handling
(changes in) mean blood pressure (mmHg)	Adults who are (not) treated for hypertension Children	Sphygmomanometer, Automatic blood pressure meter	Lowest value of 2-3 measurements, average of 2-3 measurements related to (yearly) averaged noise levels (L_{AeqT})
(changes in) ambulatory blood pressure (mmHg)	(Normotensive) adults	Ambulatory blood pressure monitor measuring blood pressure every 15, 30 or 60 minutes during 24hr	Ambulatory blood pressure levels related to continuous (personal) noise measurements ($L_{Aeq1min}$, $L_{Aeq15min}$, ..)

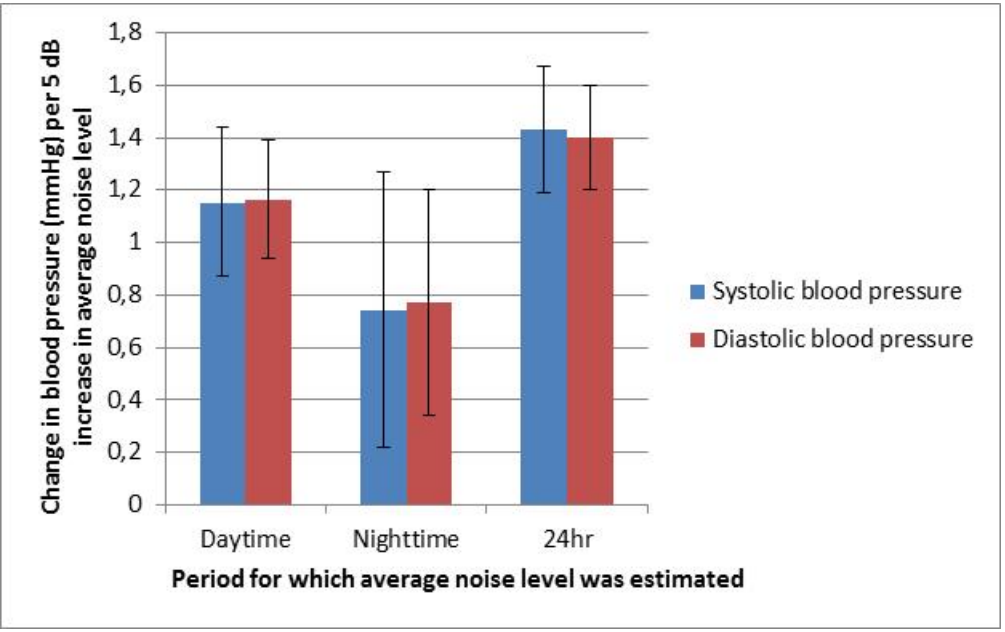
Studies working with ambulatory blood pressure

First author	Country	Design†	Population		Exposure		Blood pressure measurement
			N	Sex, age	Source	Characterization	
Chang (09)(15)	China	RM	60/66	MF, 18-32 yrs,	NS*	Personal Dosimetry (24hr)	Portabe ABPM (every 60 min, 24hr)
HYENA	Greece, UK, Italy, Sweden	RM	140	MF, 45-70 yrs	Air, Road, Indoor	Noise meter and noise recorder (night)	ABPM (every 15 min, night)

†RM = Repeated measurement study; * NS = Not able to specify; Other abbreviations: ABPM: Ambulatory Blood Pressure Measurement

- Nb: impact of short term (acute) noise exposure was investigated!

Studies working with ambulatory blood pressure



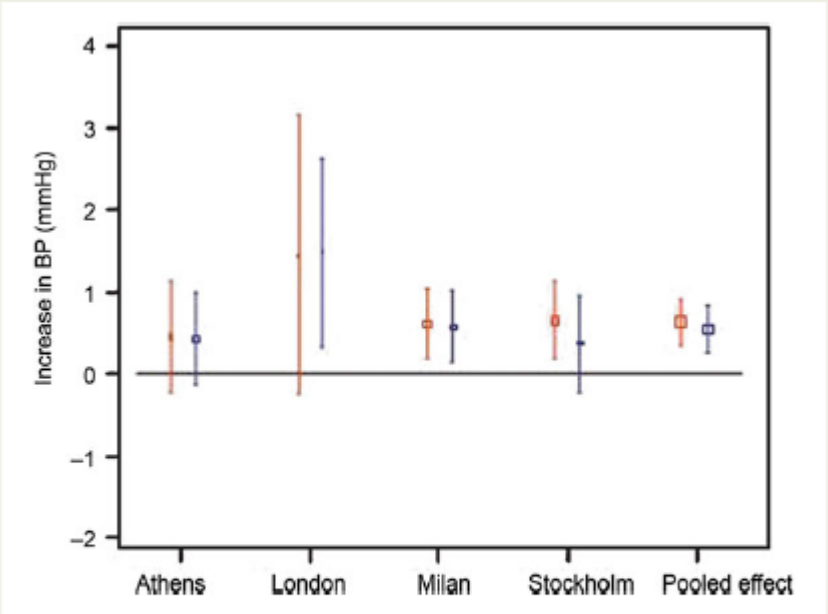
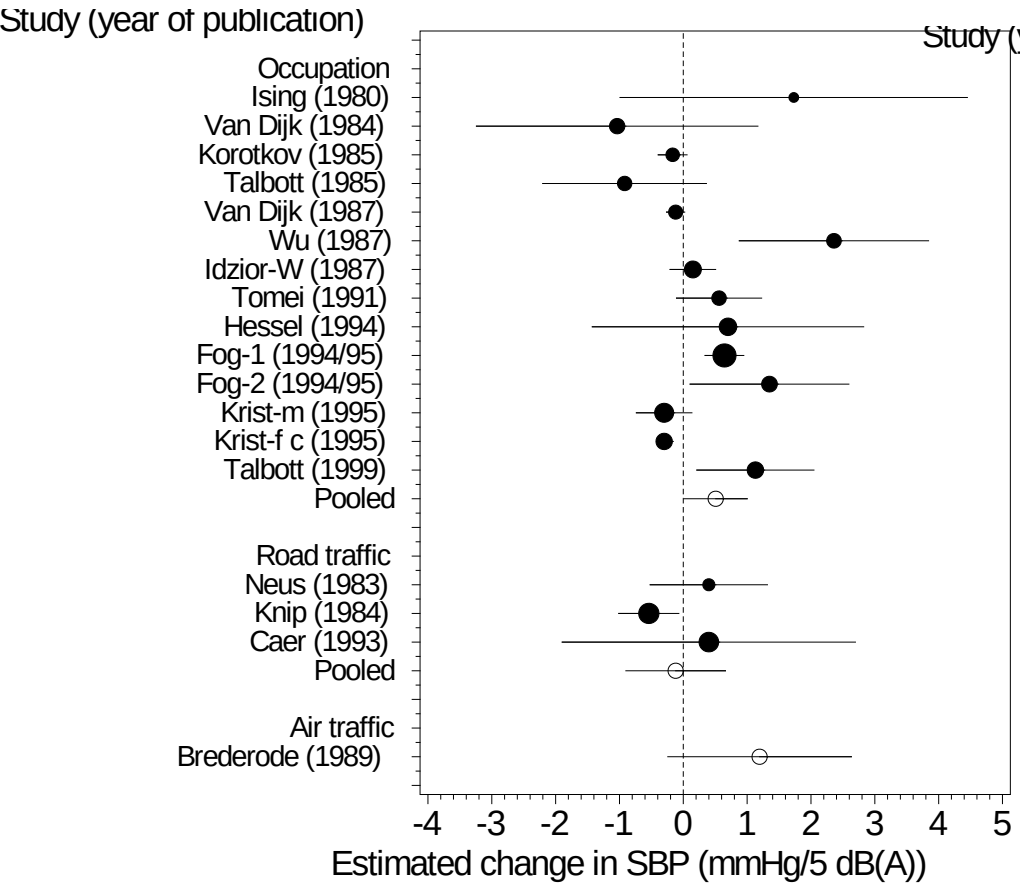
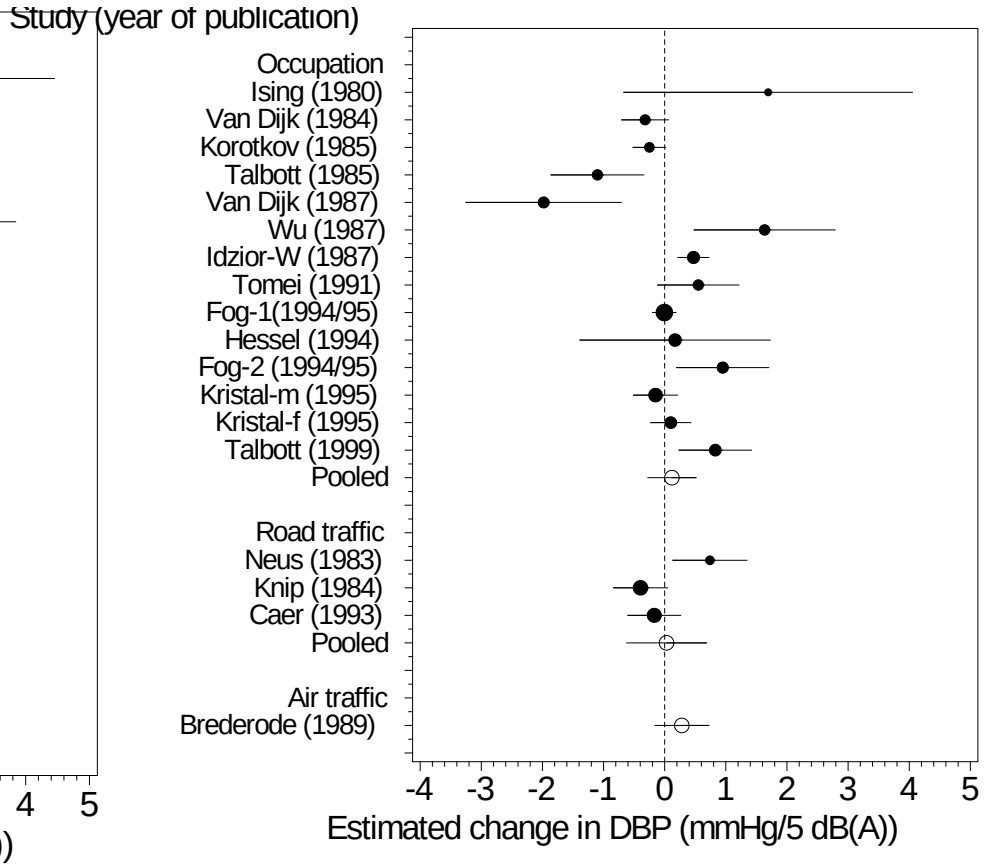


Figure 2 Centre-specific and pooled effect estimates of a 5 dB(A) increment in the equivalent noise level of 15 min (red) and 1 min (blue) before blood pressure (BP) measurement on diastolic BP

Results of studies working with mean blood pressure

- Meta-analysis Van Kempen et al(2002)
- Aim: to gain insight into the relation between noise exposure and its potential impact on cardiovascular diseases in adults
- More than 500 observational studies involving the association between noise exposure and blood pressure and/or ischemic heart disease, published between 1970 and 1999, in English, Dutch of German, were systematically identified from several bibliographic literature resources.
- Finally, 43 studies were selected for data-extraction
- Also studies investigating the impact on blood pressure were included
- Three sources: occupational, road traffic, aircraft


Study (year of publication)
Occupation
Ising (1980)
Van Dijk (1984)
Korotkov (1985)
Talbott (1985)
Van Dijk (1987)
Wu (1987)
Idzior-W (1987)
Tomei (1991)
Hessel (1994)
Fog-1 (1994/95)
Fog-2 (1994/95)
Krist-m (1995)
Krist-f c (1995)
Talbott (1999)
Pooled
Road traffic
Neus (1983)
Knip (1984)
Caer (1993)
Pooled
Air traffic
Brederode (1989)
-4 -3 -2 -1 0 1 2 3 4 5
Estimated change in SBP (mmHg/5 dB(A))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Kristal-f (1995)
Talbott (1999)
Pooled
Road traffic
Neus (1983)
Knip (1984)
Caer (1993)
Pooled
Air traffic
Brederode (1989)
-4 -3 -2 -1 0 1 2 3 4 5
Estimated change in DBP (mmHg/5 dB(A))

Results of studies working with mean blood pressure

- Review Babisch (2006):
- 62 studies that investigated the cardiovascular effects of noise in adults, and were published in the period between the 1960s and 2005.
- Finally, 7 of the 62 studies were included which investigated the effects of aircraft noise exposure in adults.

First author	Airport	Design†	Population		Exposure groups	Mean blood pressure difference*	
			N	Sex, age		Systolic blood pressure (mmHg)	Diastolic blood pressure (mmHg)
Von Eiff (1974)	Munich	CS	392	MF, 21-60 yr	<87, >95 ($L_{max, mean}$)	2	3
Knipschild (1977)	Schiphol	CS	5,828	MF, 35-64 yr	20- 60 KE	NR	NR
Schulte (1993)	Muensterland	CS	413	MF, 20-60 yr	Control area vs flight zones	-2 to +1	-1
Schulte (1993)	Franken	CS	424	MF, 40-60 yr	Control area vs 75 m area	-4 to +2	-2 to +1
Matsui (2001)	Okinawa	CS	28,781	MF, 20-79 yr	<50, 50-55, 55-60, >60 (L_{dn})	NR	NR
Goto (2002)	Fukuoka	CS	407	F	<60, ≥70 (L_{dn})	4	1
Goto (2002)	Fukuoka	CO	183	F	<60, ≥70 (L_{dn})	D: 0	D: -4

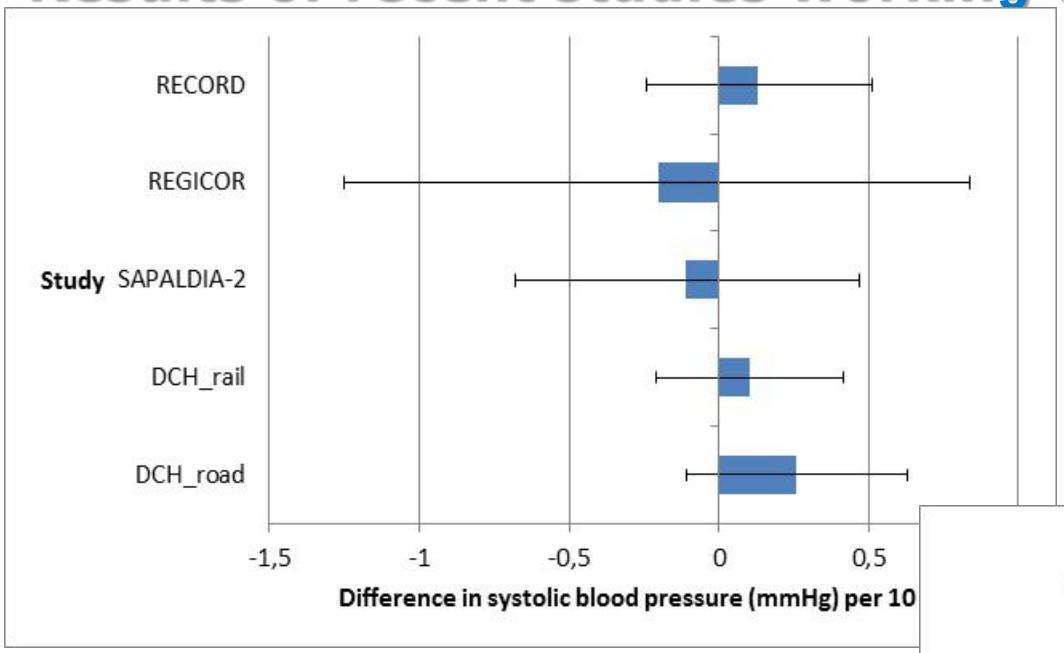
*High exposure minus low exposure (extreme group comparison); † CS = Cross-sectional study, CO = Cohort study; Abbreviations: N = sample size, M = men, F = females, yr = years, NR = Not Reported, D = Difference in change of blood pressure

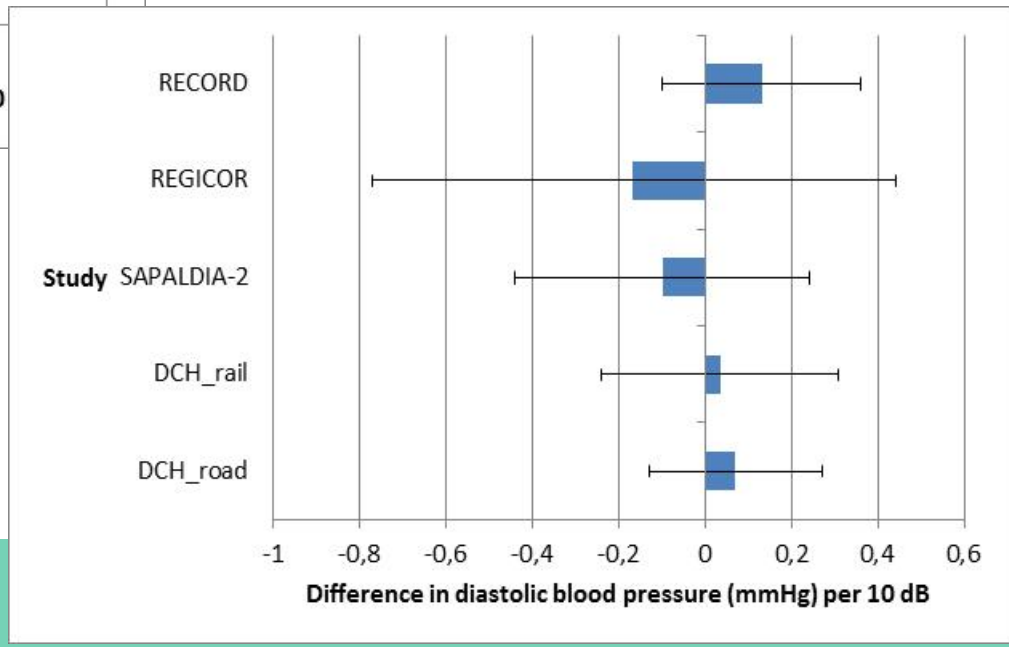
Results of recent studies working with mean blood pressure(i)

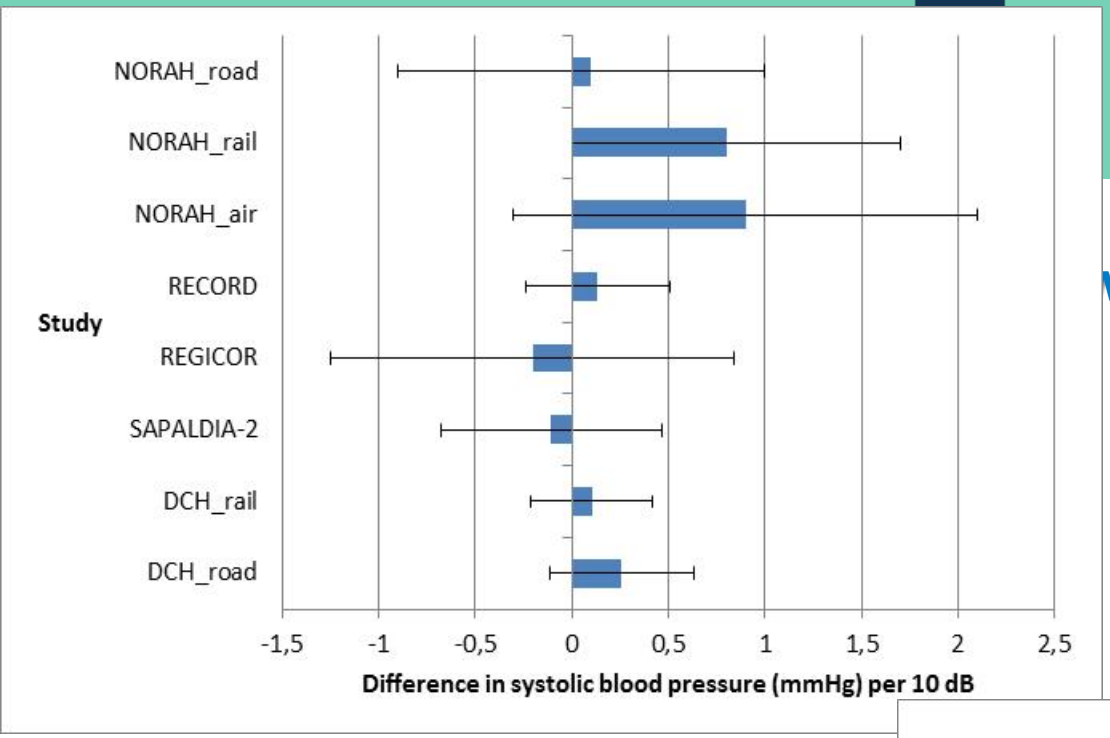
First author	City	Design†	Population		Exposure		Blood pressure measurement	Adjustment
			N	Sex, age	Source	Groups/range		
DCH	Copenhagen, Aarhus	CS	44083	MF, 50-64	Road	<56.4, 56.4 – 67.3, >67.3 (L_{den})	Automated oscillometer, lowest of 2 measurements	1 - 14
DCH	Copenhagen, Aarhus	CS	44083	MF, 50-64	Rail	< 60, 60-70, >70 ($L_{Aeq,24hr}$)	Automated oscillometer, lowest of 2 measurements	1 - 14
SAPALDIA-2	Basel, Wald, Davos, Lugano, Montana, Payerne, Aarau, Geneva	CS?	6450	MF, 28-72	Road	40 -60 (L_{day})	Automatic riva-rocci meter, average of 2 measurements	1, 4, 15-25
REGICOR	Girona	CS?	1926	MF, 36-82	Road	L_{night}	Automatic blood pressure meter, last of 2 measurements	1, 2, 5, 6, 9, 10, 15, 13, 18, 33-35
RECORD	Ile de France	CS	7068	MF, 30-79	Transport	30 – 45, 45-65, 65-80 (Overall L_{den})	Manual mercury sphygmomanometer, mean of last 2 measurements	26-32

1 = Age, 2 = gender, 3 = calender-year, 4 = area, 5 = smoking, 6 = BMI, 7 = length of school attendance, 8 = municipality SES, 9 = alcohol intake, 10 = physical activity, 11 = NO_x, 12 = season, temperature, 14 = humidity, 15 = education, 16 = full-time employment status, 17 = marital status, 18 = diabetes, 19 = mean pulse, 20 = antihypertensive medication, 21 = self-reported physician diagnosed hypertension, 22 = hearing impairment, 23 = noise at work, 24 = rail traffic noise, 25 = NO_2, 26 = individual SES variables, 27 = time of blood pressure measurement, 28 neighborhood social factors, 29 = road traffic air pollution, 30 = perceived occupational noise exposure, 31 = risk factors of hypertension, 32 = road traffic related annoyance, 33 = mediteranian diet, 34 = deprivation, 35 = indoor railway noise

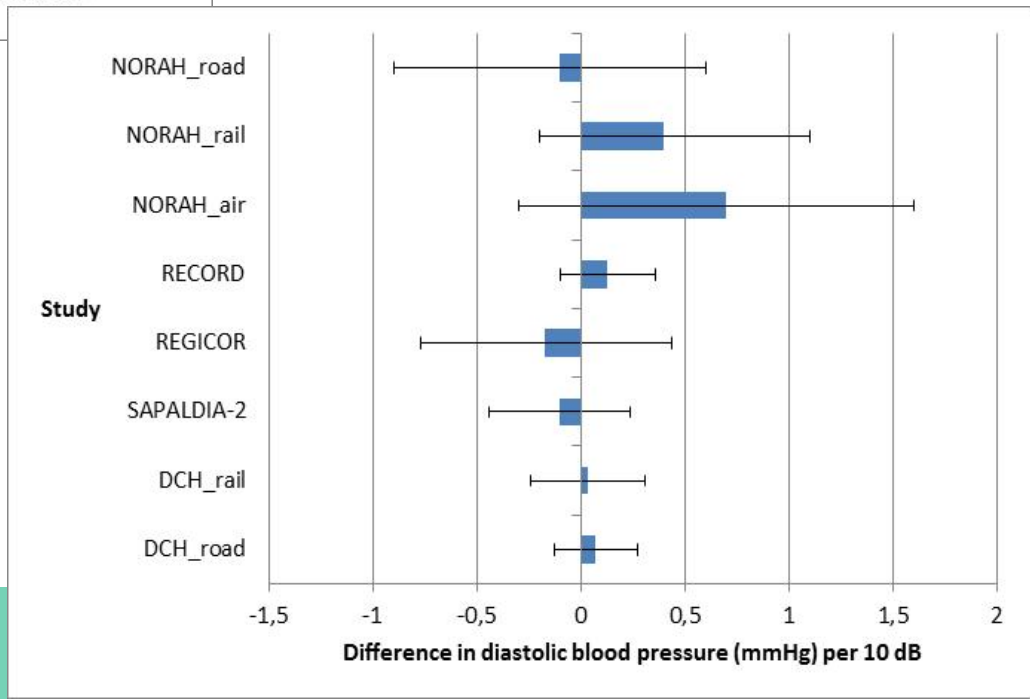
Results of recent studies working with mean blood pressure







vith mean blood pressure

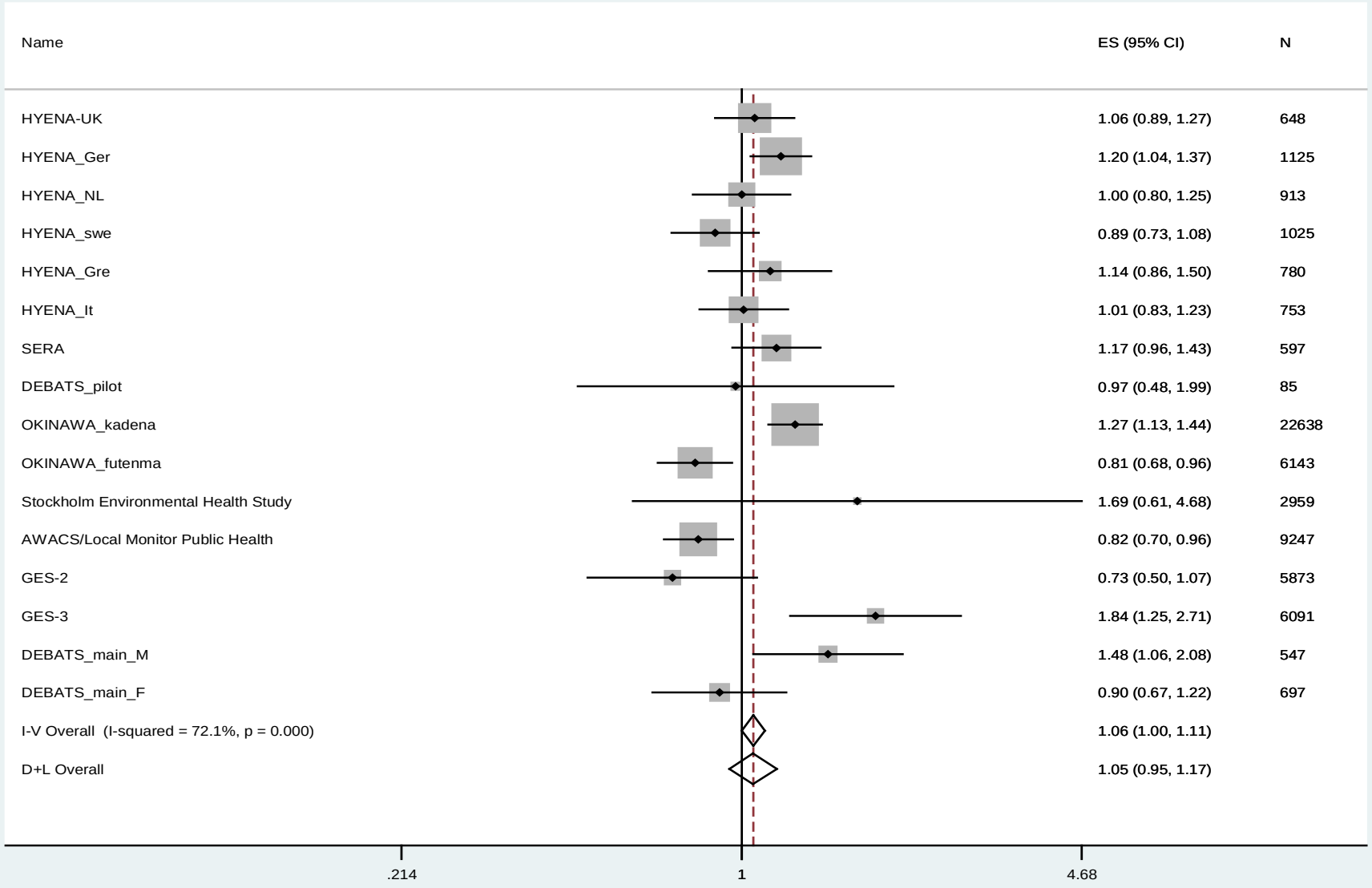


Studies investigating the impacts on hypertension

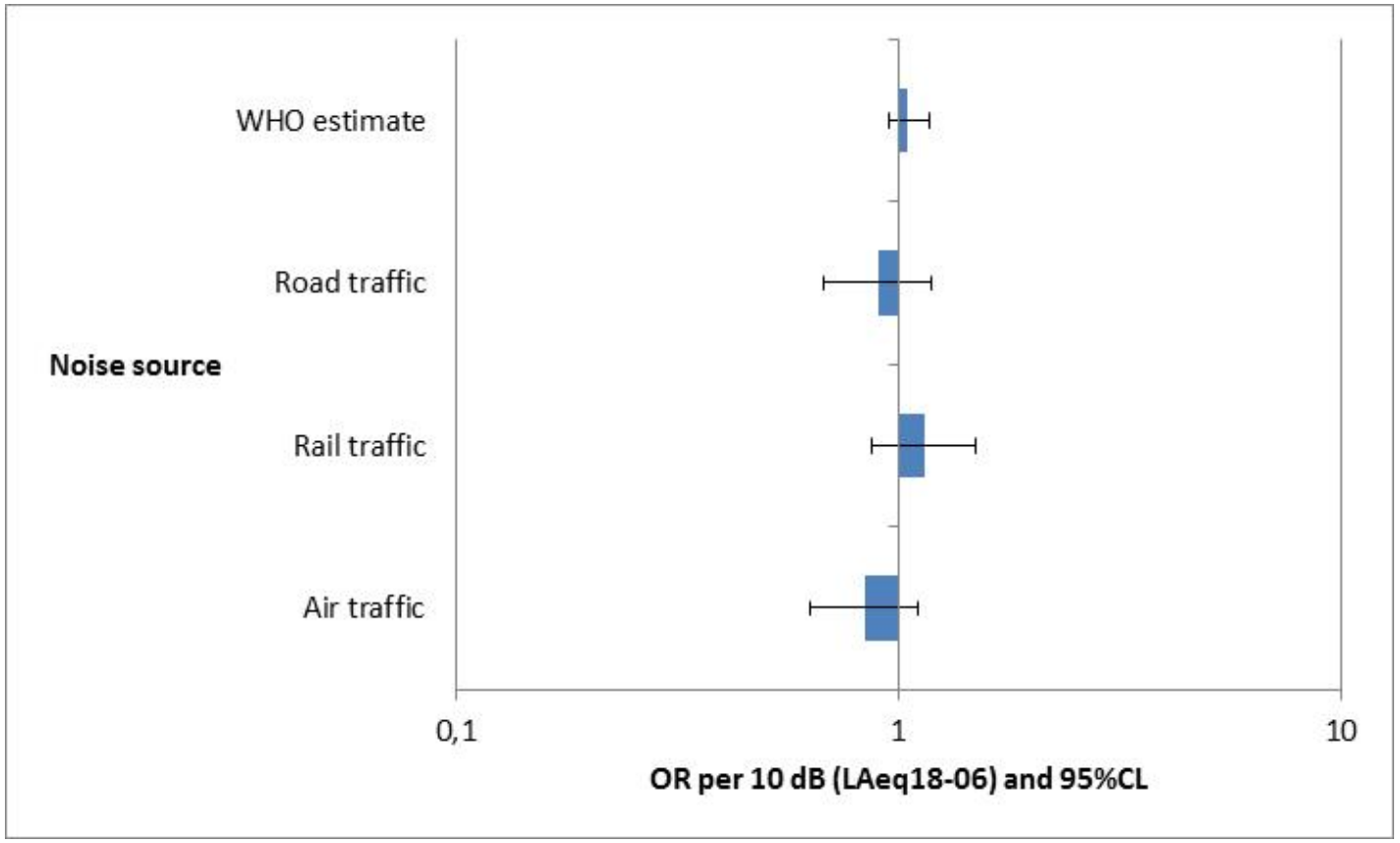
Overview of characteristics of the 11 selected studies investigating the association between aircraft noise and hypertension

Study	Country	Design*)	N†)	Sex and age (yrs)	Type‡)	Exposure characterization$^{\Psi}$)	Ascertainment hypertension**)
Knipschild-1	NL	CS	5828	MF, 35-64	C	Aircraft noise contours (2)	1, 2
OKINAWA	Japan	CS	28781	MF, 20-79	M	Aircraft noise levels (2)	1
SEHS	Sweden	CS	2959	MF, 19-80	C	Aircraft noise levels (1)	2
HYENA	Europe	CS	4861	MF, 45-70	C	Aircraft noise levels (1)	1, 2
SDPP	Sweden	CO	5712	MF,35-56	C	Aircraft noise levels (1)	1, 2
DEBATS-pilot	France	CS	85	MF, 21-84	C	Aircraft noise levels (1)	1, 2
DEBATS-main	France	CS	1244	MF, 18-90	C	Aircraft noise levels (1)	1, 2
AWACS	NL	CS	9365	MF, 17-65	M,C	Aircraft noise levels (1)	2
SERA	Italy	CS	597	MF, 45-70	C	Aircraft noise levels (1)	1, 2
GES-2	NL	CS	5873	MF, 18yrs and older	C	Aircraft noise levels (1)	2
GES-3	NL	CS	6091	MF, 18yrs and older	C	Aircraft noise levels (1)	2

*) CS = Cross-sectional study, Eco = Ecological study, CO = Cohort study; †) N = Number of participants; ‡) Type of aircraft noise: C = civil aircrafts, M = military aircrafts; $^{\Psi}$ 1 = modelled, 2= measured; **) 1=Measurement/clinical interview, 2=self-reported


Name
ES (95% CI)
N
HYENA-UK
1.06 (0.89, 1.27)
648
HYENA_Ger
1.20 (1.04, 1.37)
1125
HYENA_NL
1.00 (0.80, 1.25)
913
HYENA_swe
0.89 (0.73, 1.08)
1025
HYENA_Gre
1.14 (0.86, 1.50)
780
HYENA_It
1.01 (0.83, 1.23)
753
SERA
1.17 (0.96, 1.43)
597
DEBATS_pilot
0.97 (0.48, 1.99)
85
OKINAWA_kadena
1.27 (1.13, 1.44)
22638
OKINAWA_futenma
0.81 (0.68, 0.96)
6143
Stockholm Environmental Health Study
1.69 (0.61, 4.68)
2959
AWACS/Local Monitor Public Health
0.82 (0.70, 0.96)
9247
GES-2
0.73 (0.50, 1.07)
5873
GES-3
1.84 (1.25, 2.71)
6091
DEBATS_main_M
1.48 (1.06, 2.08)
547
DEBATS_main_F
0.90 (0.67, 1.22)
697
I-V Overall (I-squared = 72.1%, p = 0.000)
1.06 (1.00, 1.11)
D+L Overall
1.05 (0.95, 1.17)
.214
1
4.68

Noise and hypertension in NORAH



In summary

- No consistent findings in the relationship between transportation noise levels and systolic or diastolic blood pressure can be seen across the studies as yet
- Although effect sizes are somewhat larger, the BP results of NORAH more or less fall within the range of what is observed among other studies
- For the association between aircraft noise and hypertension weak associations were found in the literature
- The hypertension results of NORAH fall within the range of what other studies found

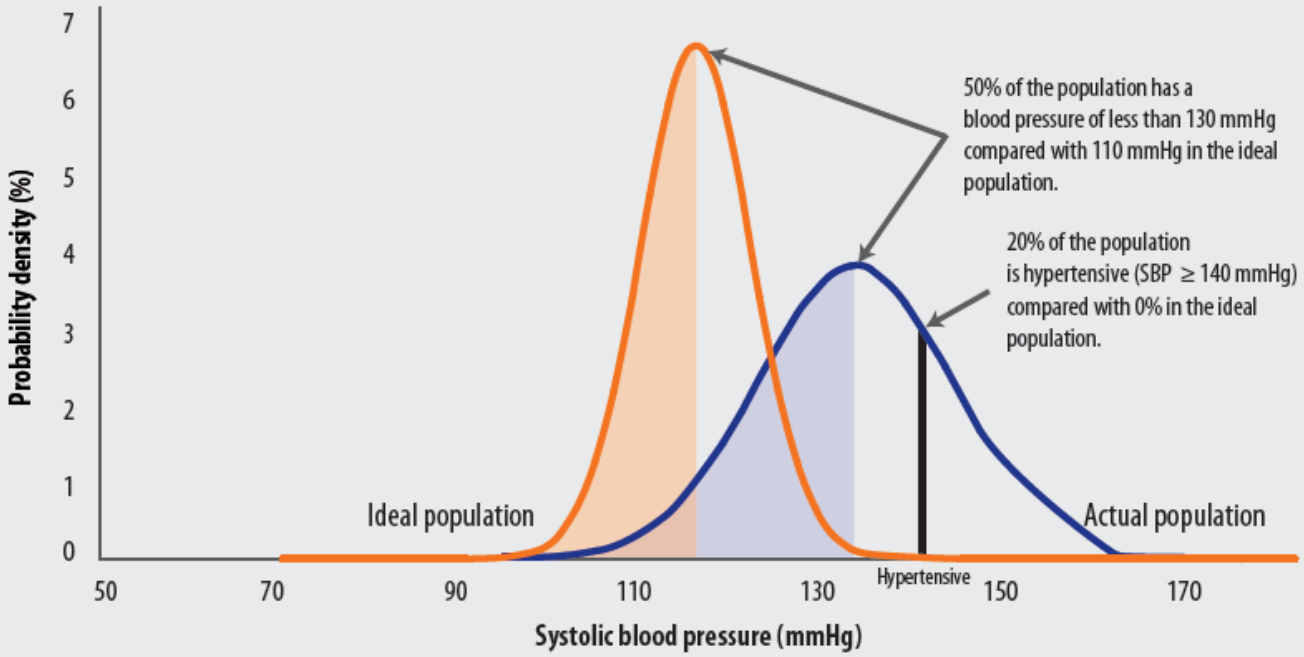
Interpretation

- Reversibility of the effects:
- What happens when noise levels decrease?
- Unknown to what extent slight BP increases affect health of a person

  → small bp elevations: what is clinical significant? Or is it chance?

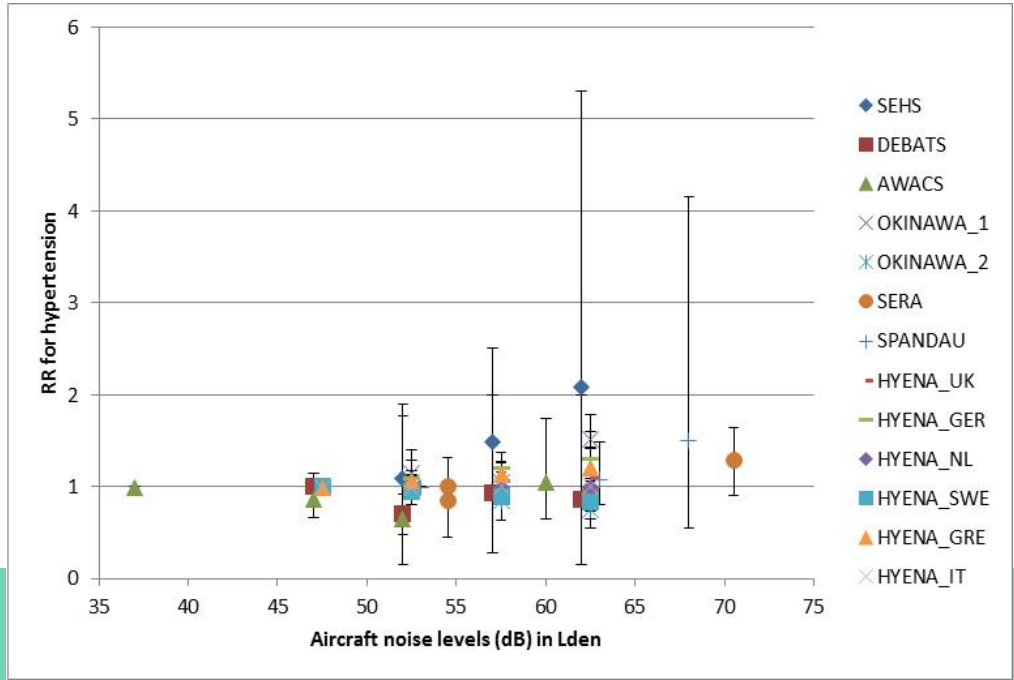
Blood pressure and its relevance for public health

Figure 3: An observed population distribution of average systolic blood pressure (SBP, right-hand distribution) and the ideal population distribution of average systolic blood pressure (left-hand distribution).



Interpretation

- The mechanism of noise affecting cardiovascular system is plausible
- Due to inconsistent findings no exposure-effect relations can be derived/exist for blood pressure
- For the association with hypertension a new, but weak relation was derived
- There is uncertainty about the shape of this relation



Interpretation

- Impact of noise on (high) blood pressure is investigated in only a few populations, including children
- The effect of noise exposure in children does not appear to be different than that in adults. → However, children may be longer exposed throughout their life than the adults that were studied

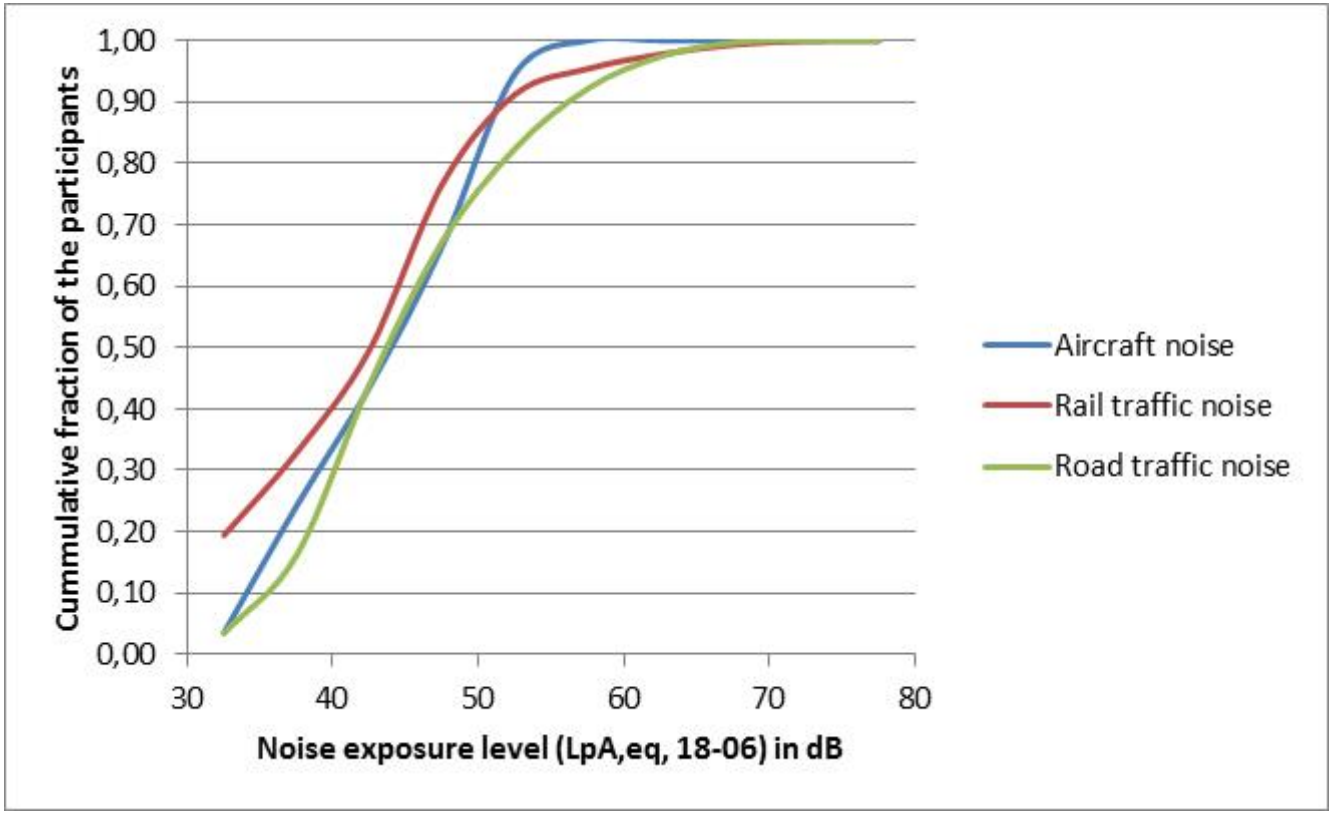
- The impact of noise on blood pressure was mainly investigated by cross-sectional studies: exposure and effect were measured at the same time. It is unclear when and how fast the effect of noise emerges

Interpretation

- Other limitations of the studies investigating the impacts of noise on blood pressure:
- Sensitive subjects tend to move out of the polluted areas, dilluting the effects of noise
- High blood pressure medication might affect the blood pressure readings, but
- Exclusion of both hypertensive and hypotensive persons dilutes the effect of blood pressure differences
- Possible exposure misclassification in the older studies due to inability to apply individual exposure estimates

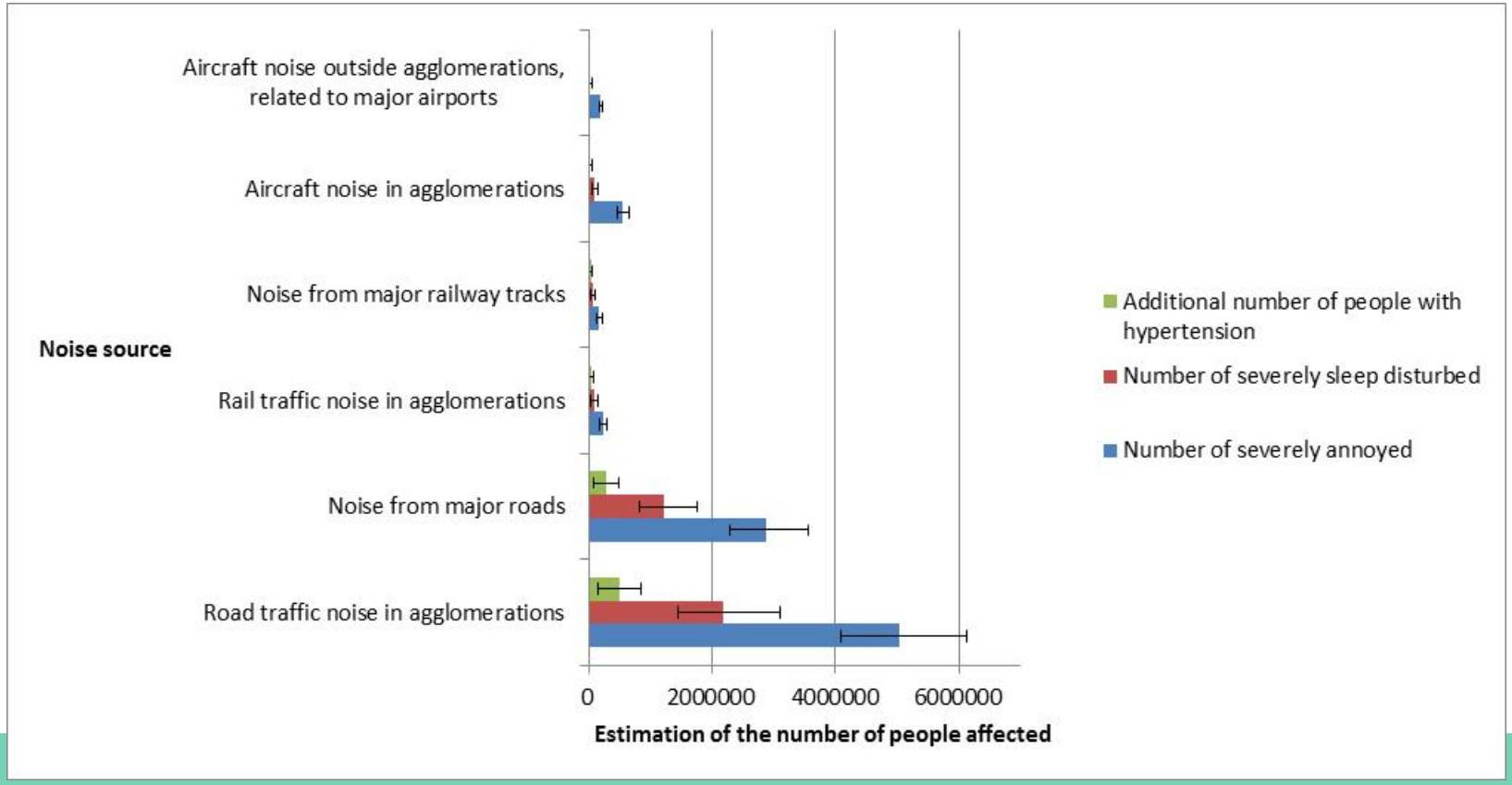
Thank you for your attention!

Extra sheets


Cummulative fraction of the participants
1,00
0,90
0,80
0,70
0,60
0,50
0,40
0,30
0,20
0,10
0,00
30
40
50
60
70
80
Noise exposure level (LpA,eq, 18-06) in dB
Aircraft noise
Rail traffic noise
Road traffic noise

Number of people affected

Figure. Estimated prevalence of severe annoyance, severe sleep disturbance and hypertension among adults due to exposure ≥ 55 dB (L_{den}) or ≥ 50 dB (L_{night}) to 3 noise sources in Europe (Source: Houthuijs et al., 2014)



Studies investigating the impact on blood pressure

Mean blood pressure

- Traditional office blood pressure measurement: “White coat” effect

Ambulatory blood pressure

- No “white coat” effect
- Truer reflection of the ‘real’ blood pressure
- Better predictor for the risk on cardiovascular diseases