inter•noise 2009
innovations in practical noise control

2009 August 23-26
Ottawa, Canada

Noise-induced sleep disturbances and after-effects on performance, wellbeing and health

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IfADo

DLR

George Thiessen
NRC, Ottawa, CAN

Sleep disturbances – Traffic volume

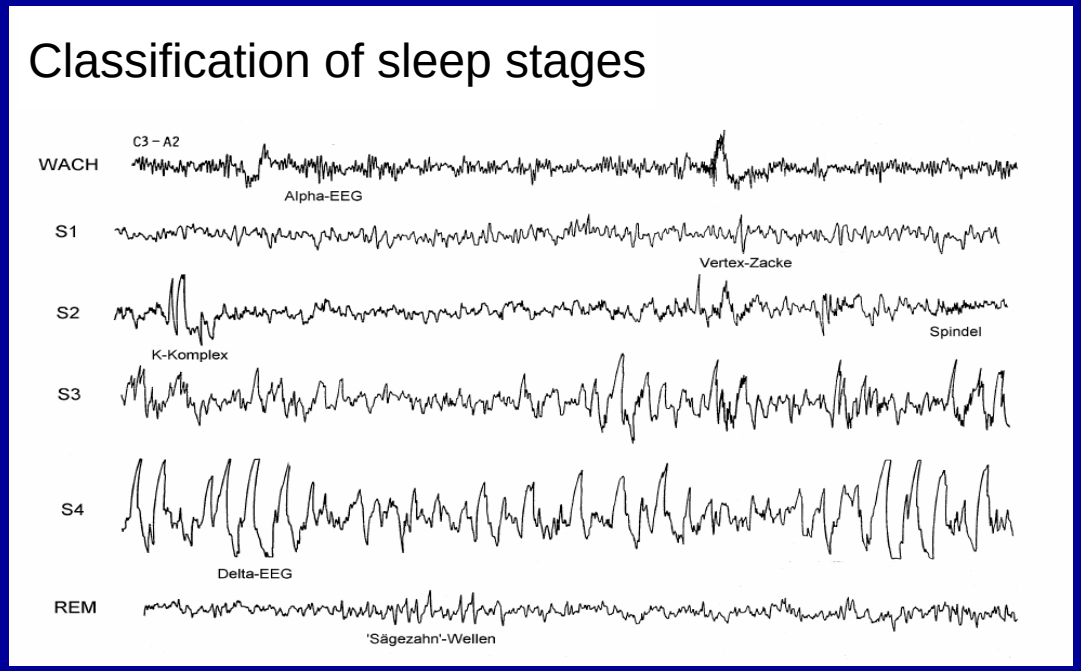
Sleep disturbances caused by

- underlying diseases
- environmental influences: **Transportation noise**

Increase of traffic volume (EU 1997–2020)

Passenger transport	+ 40 %
Freight transport	+ 64 %

Systematic research

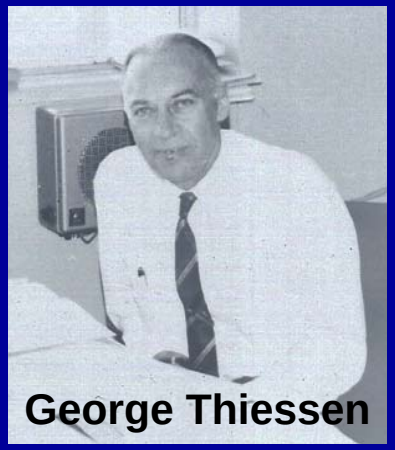


Suitable methods for the recording and evaluation available at the end of the 60s

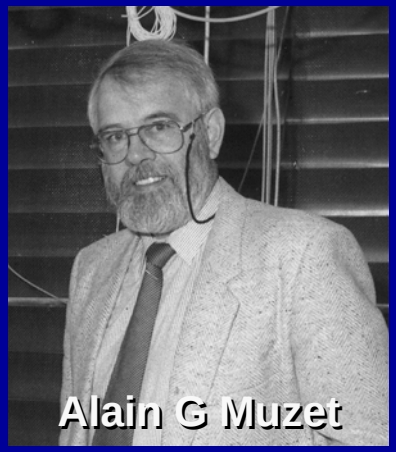
Research on noise-induced sleep disturbances

Jerome S Lukas

Stanford Research Center
Menlo Park, CA, USA,
Psychologist



NRC, Ottawa, CAN,
Physicist

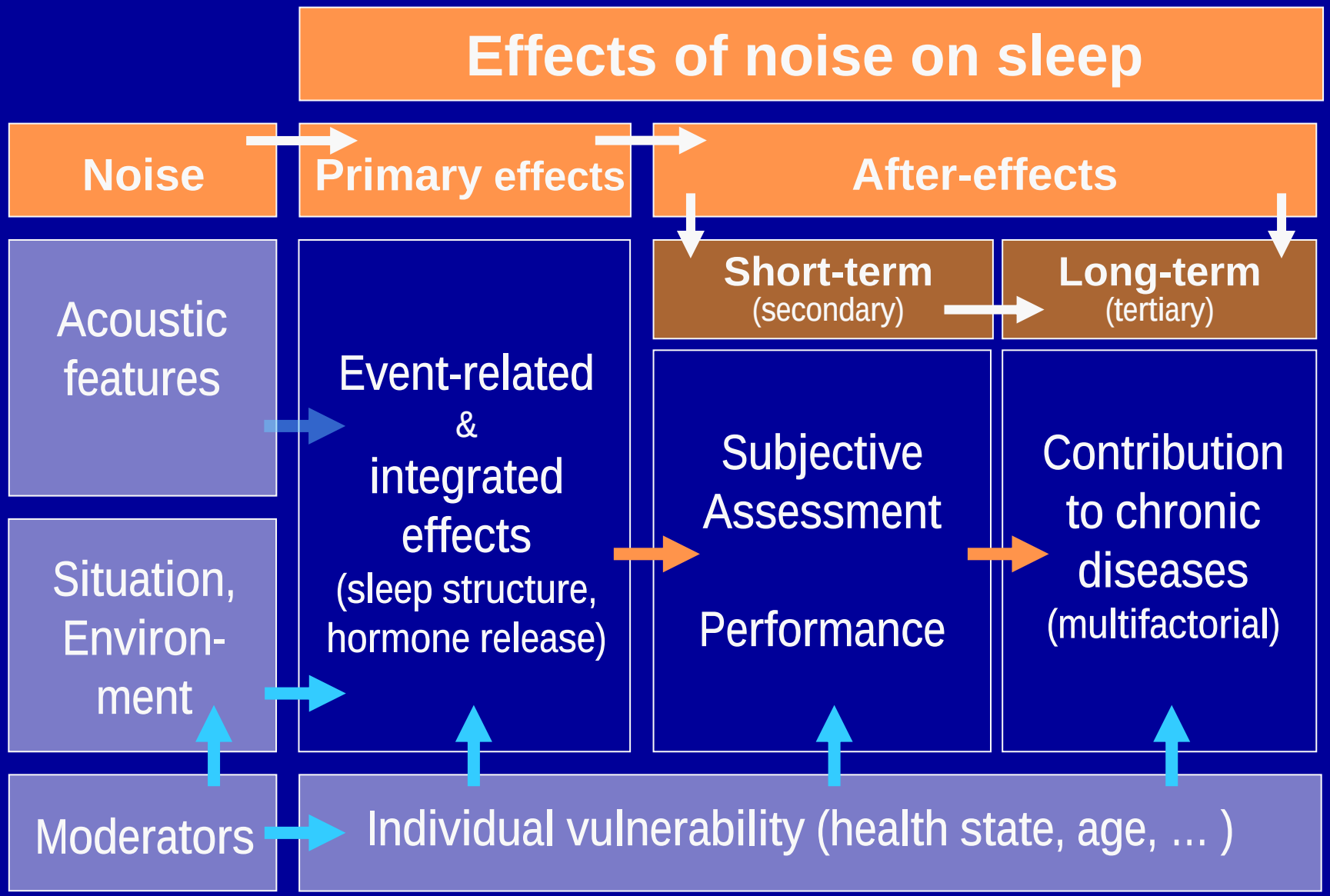


CNRS, Strasbourg/
France, Physician

Universities Essen, Bochum,
Mainz, Düsseldorf, Dortmund,
Physician

University of
Gothenburg
Psychologist

Hypothesis: noise-induced sleep disturbances

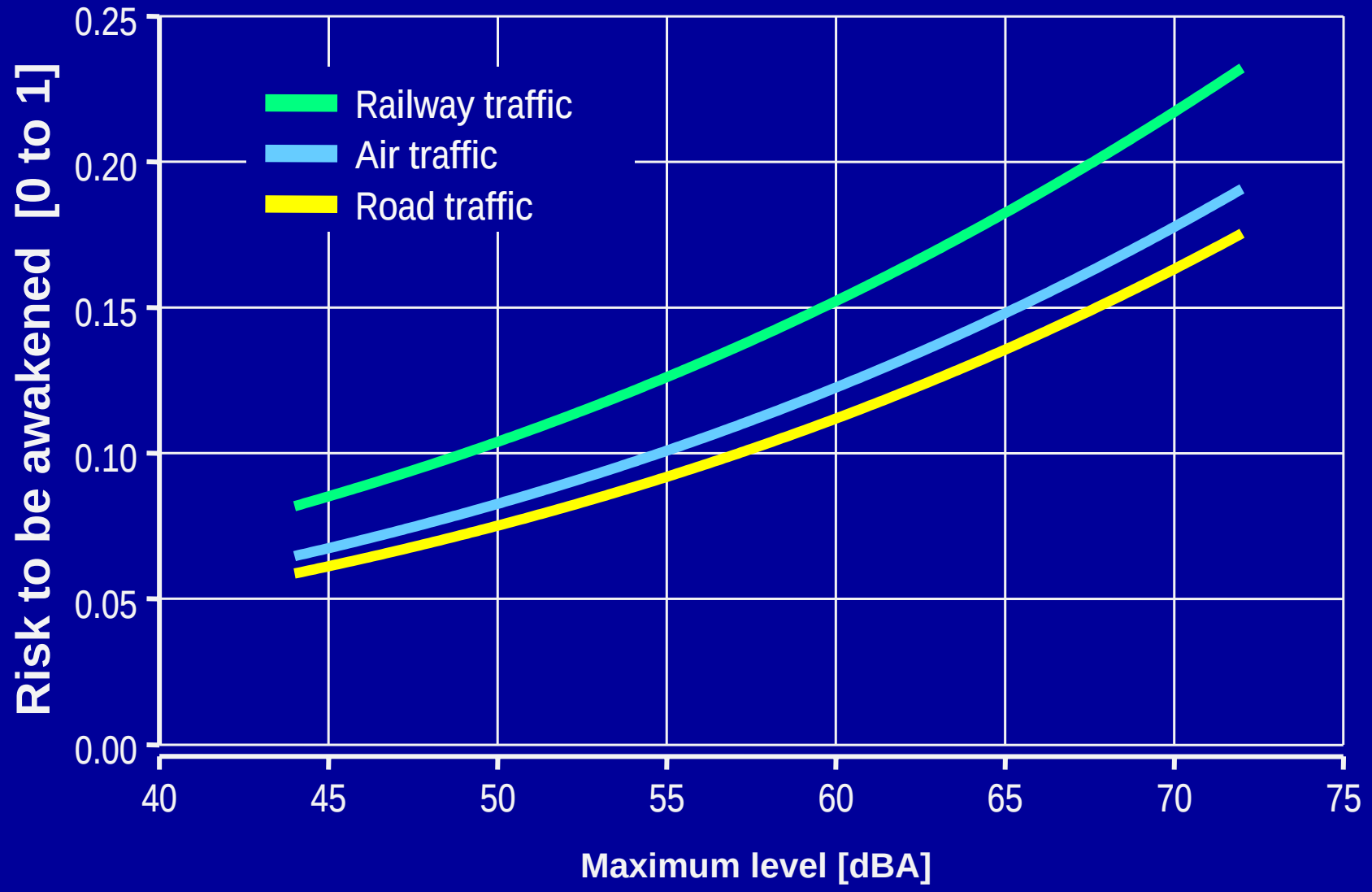


Primary effects

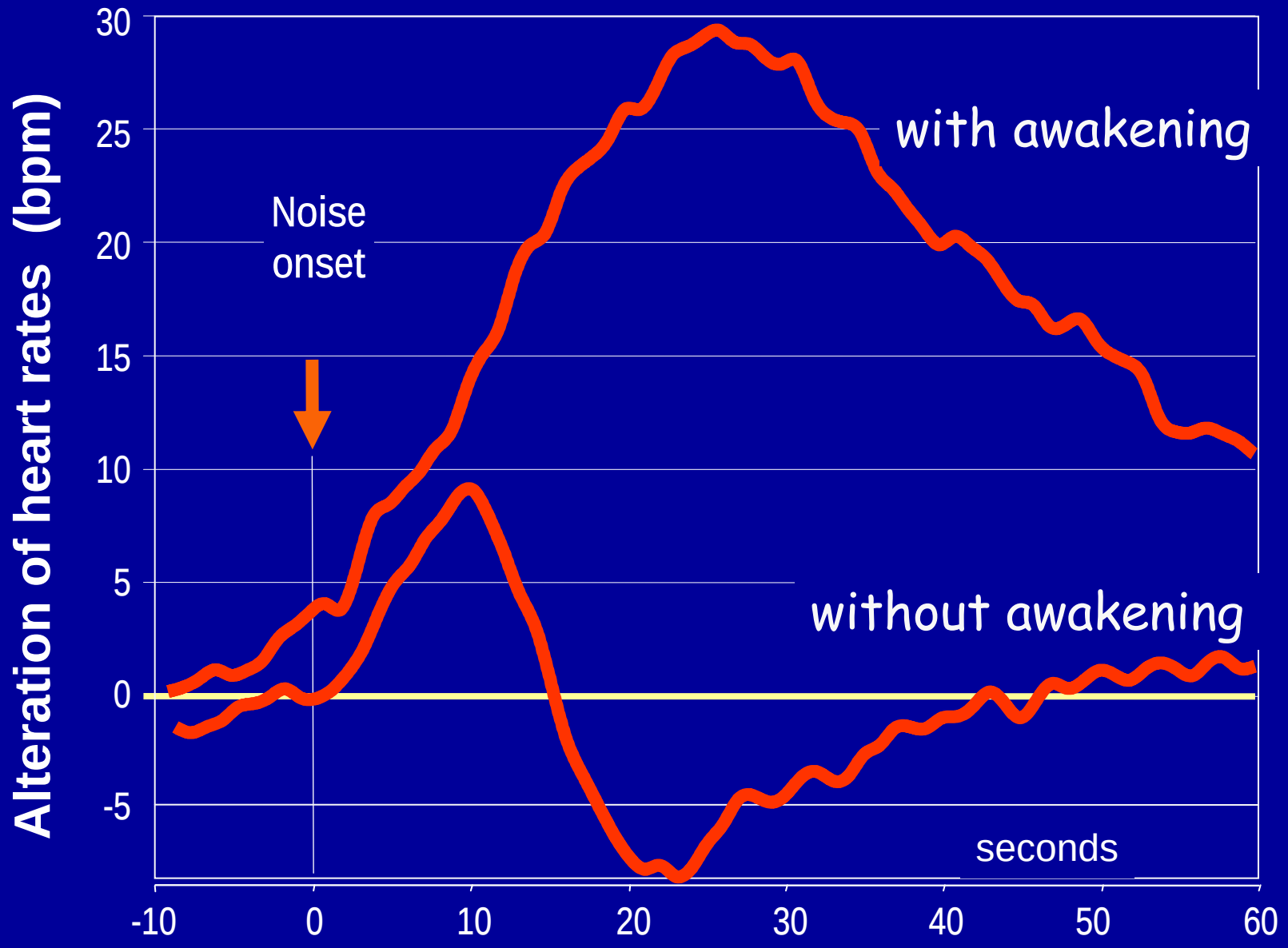
acute (event-related)

cortical, autonomic & motor arousals

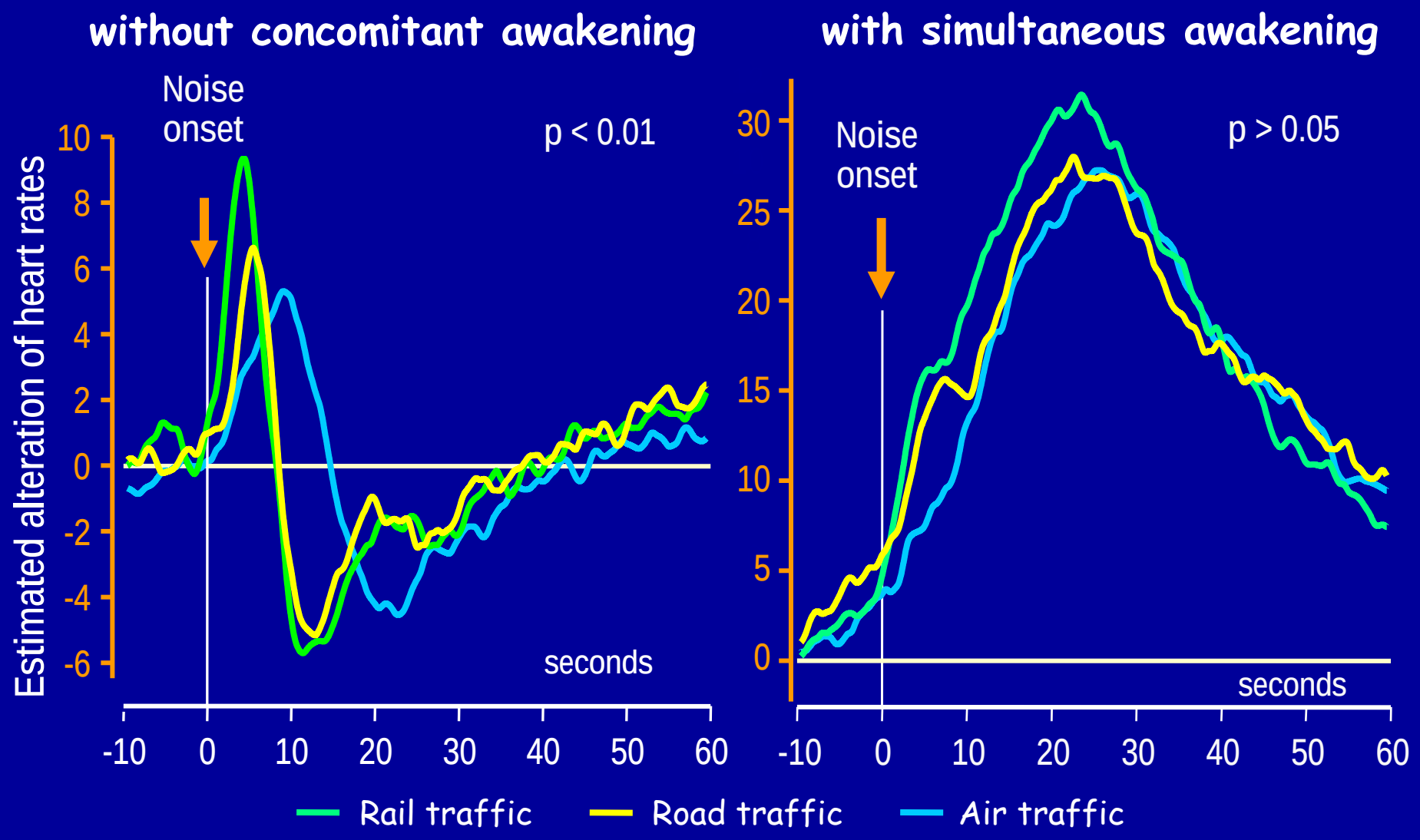
Event-related awakenings (ERA)
Dose-response curves



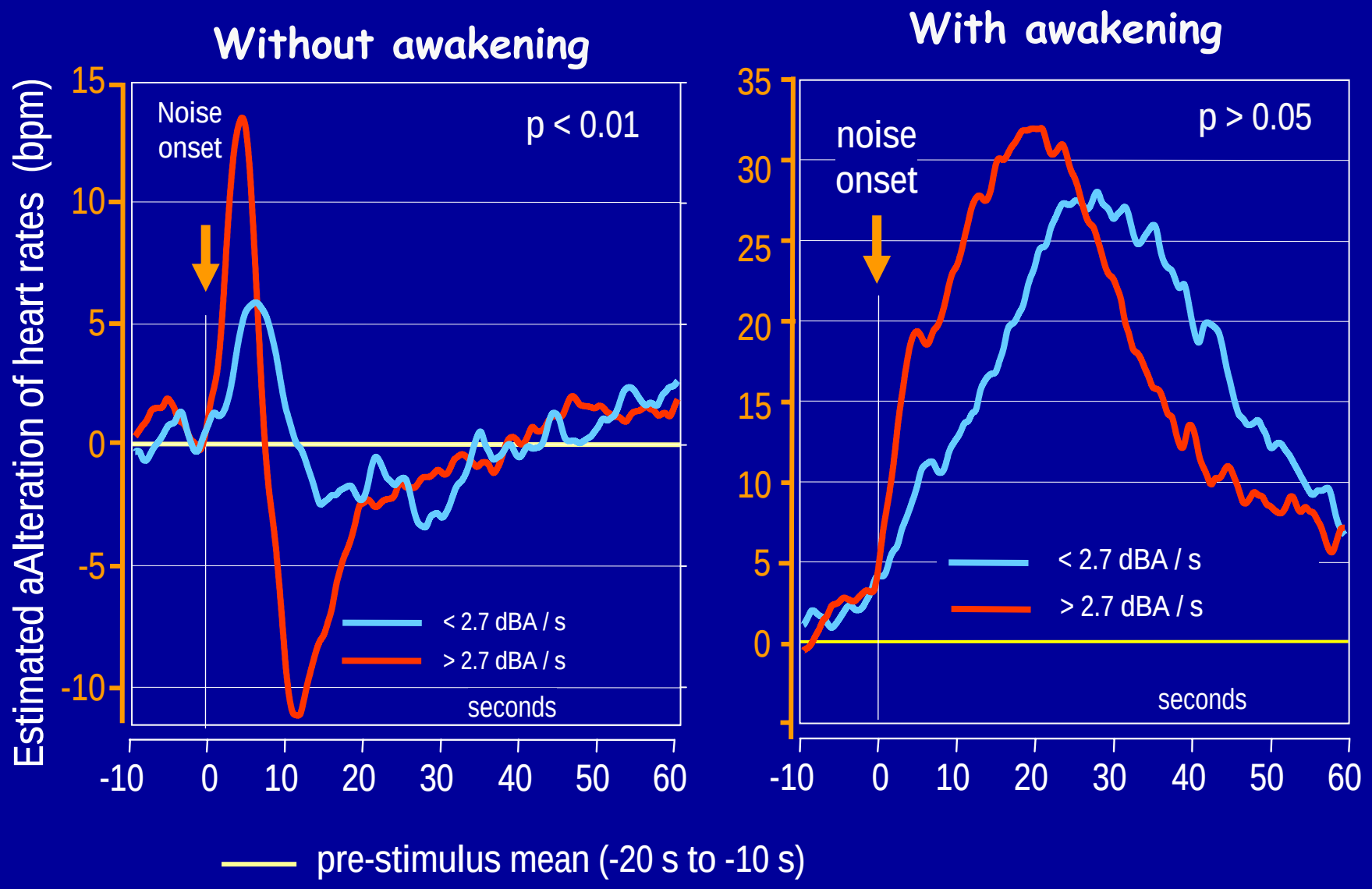
Event-related cardiac arousals during sleep



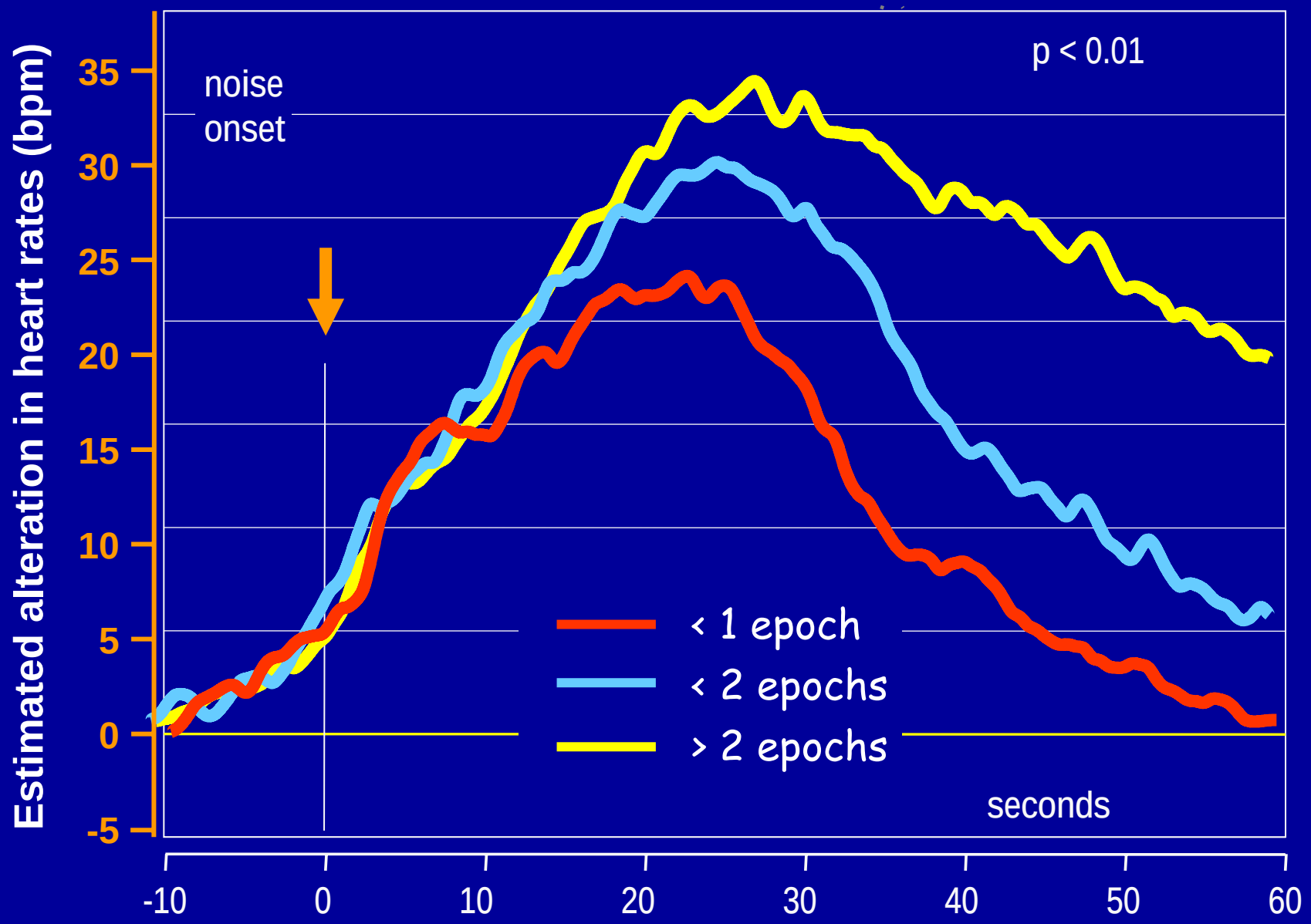
Event-related cardiac arousals effects of traffic mode



Event-related cardiac arousals effects of rise time (railway noise)



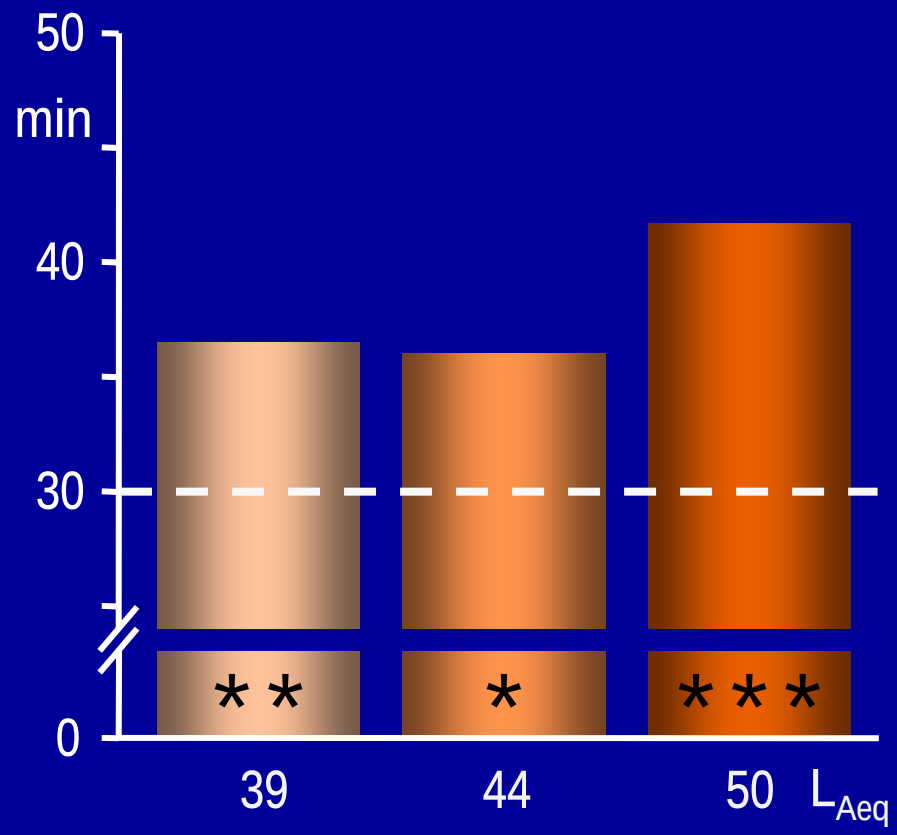
Event-related cardiac arousals

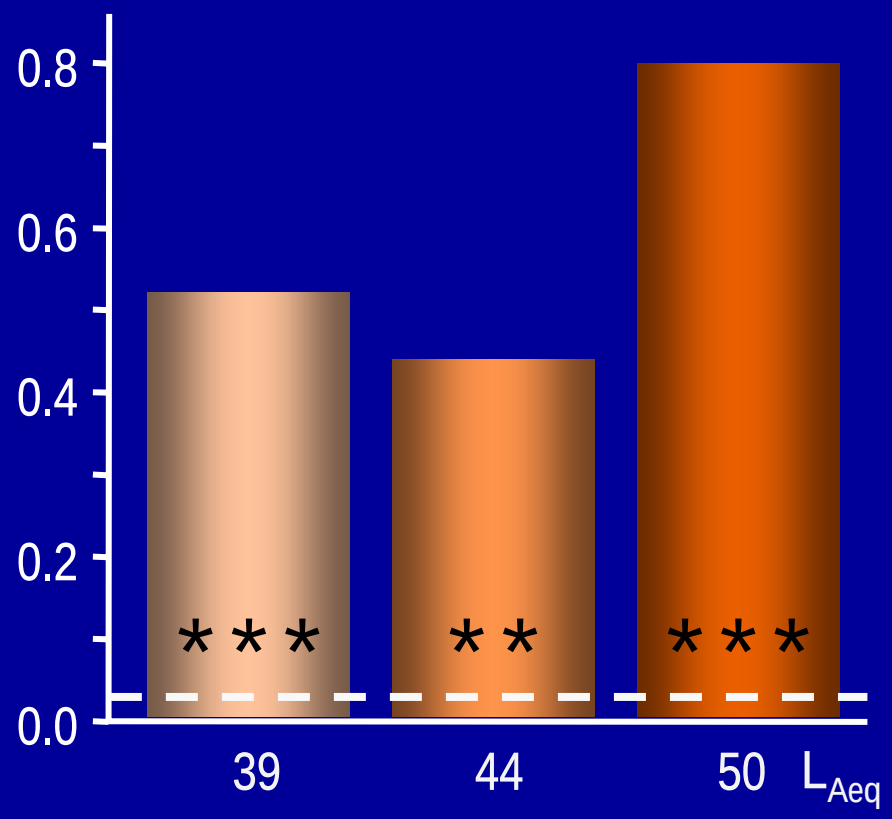


Primary effects

integrated effects
on sleep structure

Sleep structure – equivalent noise level





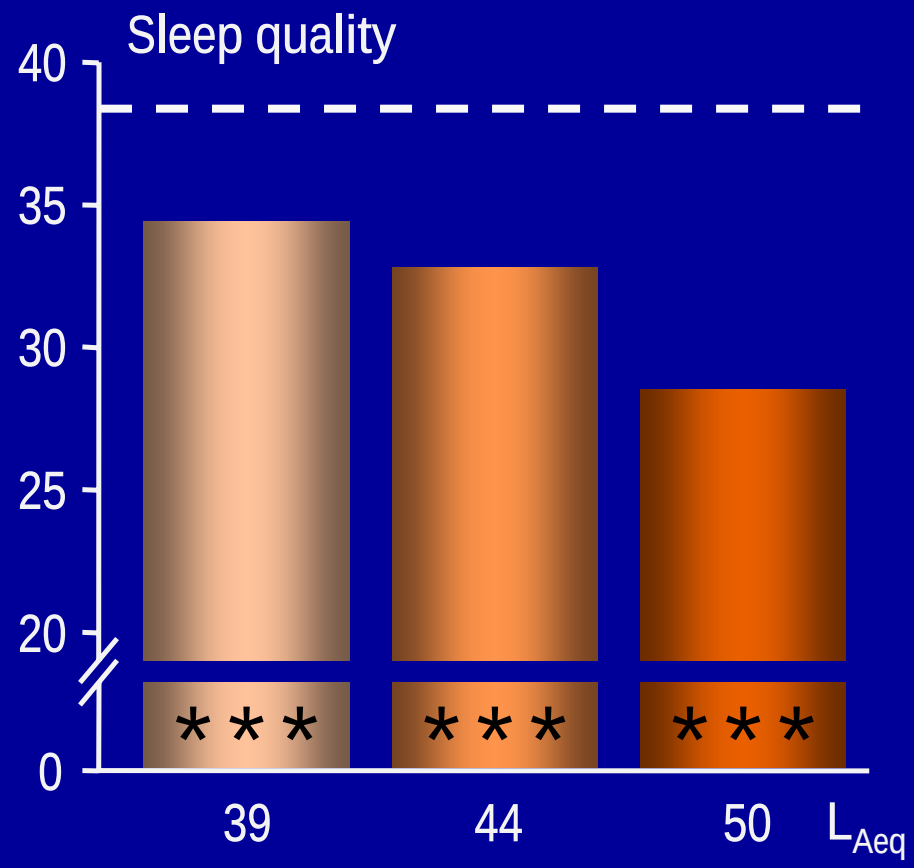
– – - Average in quiet nights

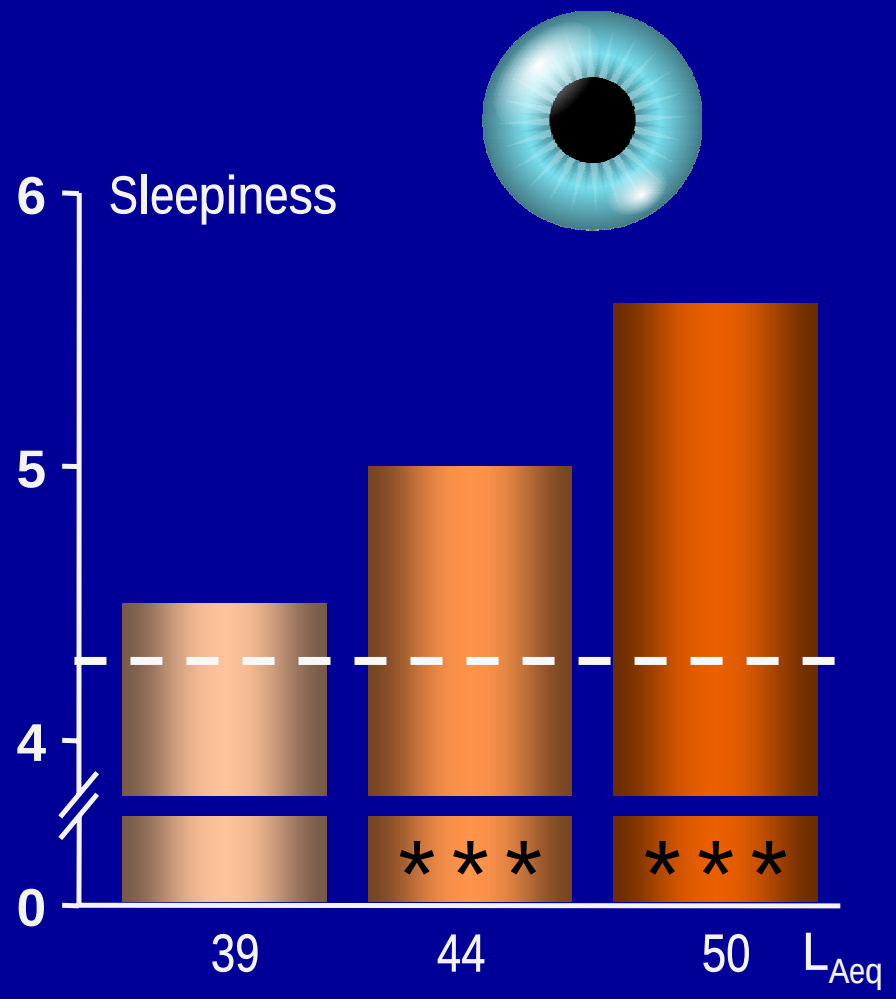
After effects

Post-awakening and consecutive wake period

Short-term (secondary) effects

Sleep quality and fatigue – equivalent noise level

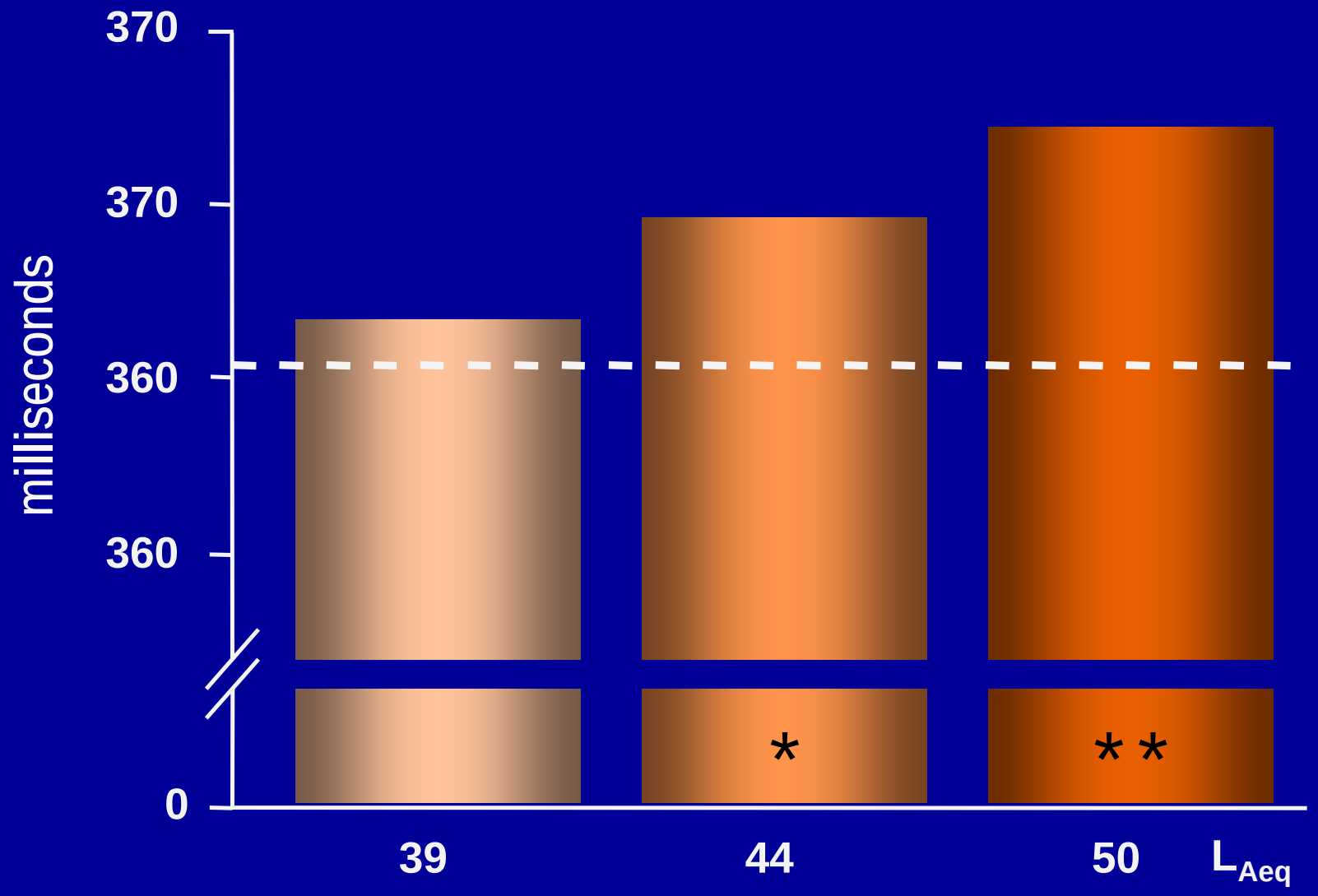




– – – Average in quiet nights

Performance – executive functions

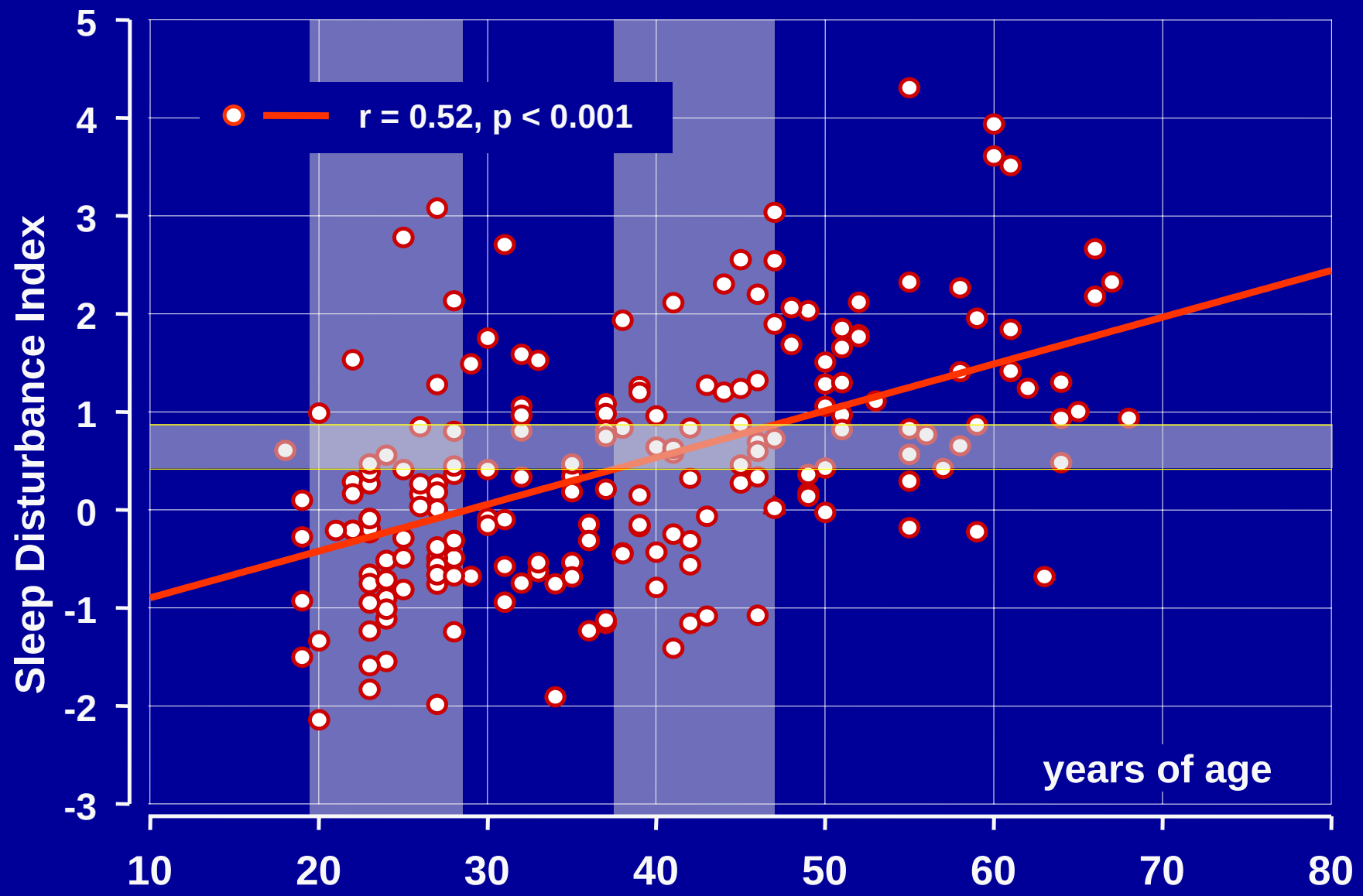
Reaction time in a switch task related to the equivalent noise level



Consequences for health

Long-term after-effects

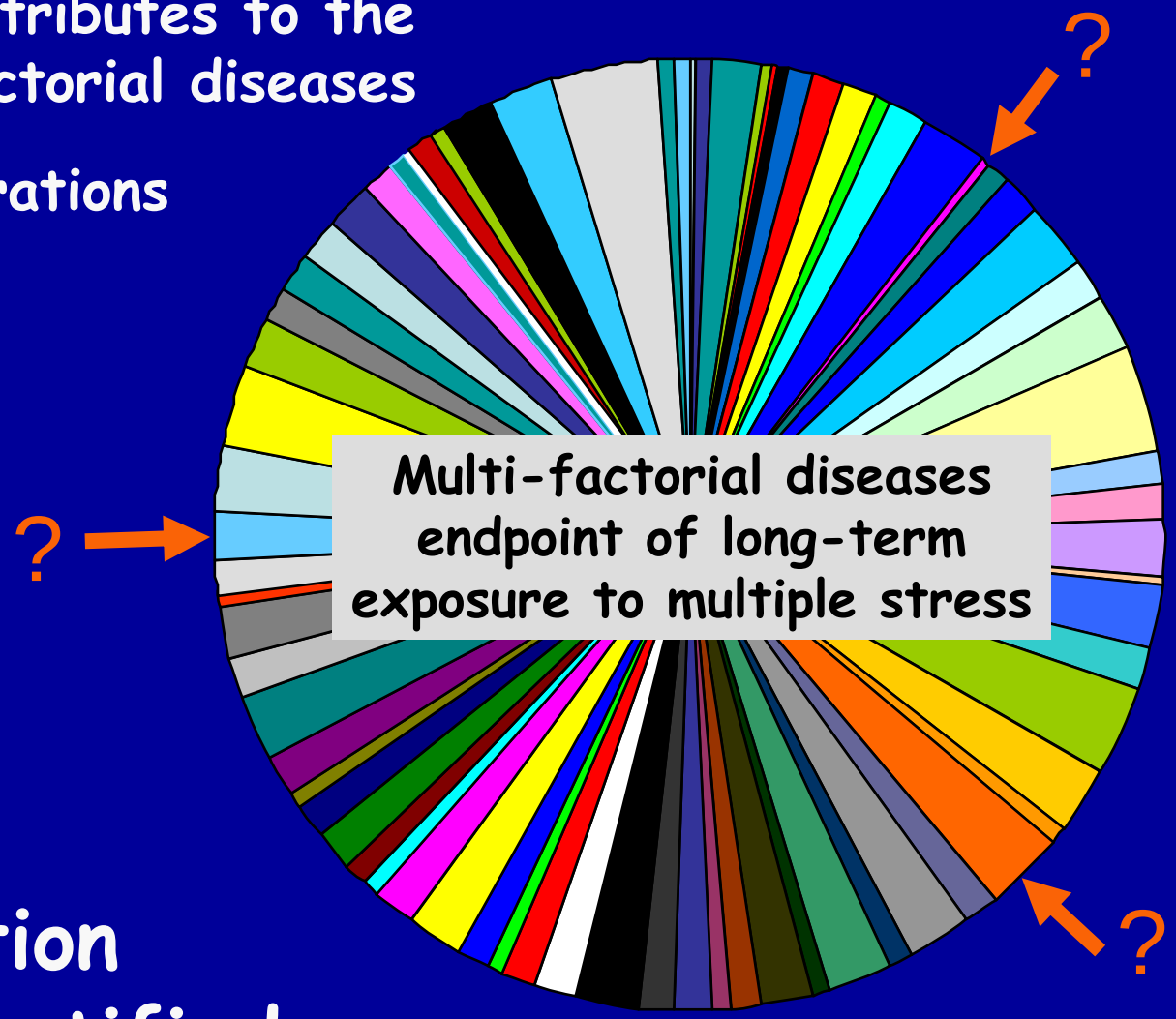
Nocturnal noise – sleep as in older persons



Epidemiological studies

Nocturnal noise contributes to the genesis of multi-factorial diseases

- non-specific alterations
- no habituation



The contribution cannot be quantified

Nocturnal noise exposure is a health risk

Noise abatement is essential for public health care

Cesar forbade nocturnal traffic of carriages

Goscinny/Uderzo

Goal: avoid diseases

Limits are not available

Reduce acute effects
to avoid
long-term effects

Protection goal

Reduce the number of awakenings

Why awakenings ?

- strongest form of activation
- cause strong autonomic arousals
- potentially recalled (-> subjective sleep quality)

Why EEG-awakenings ?

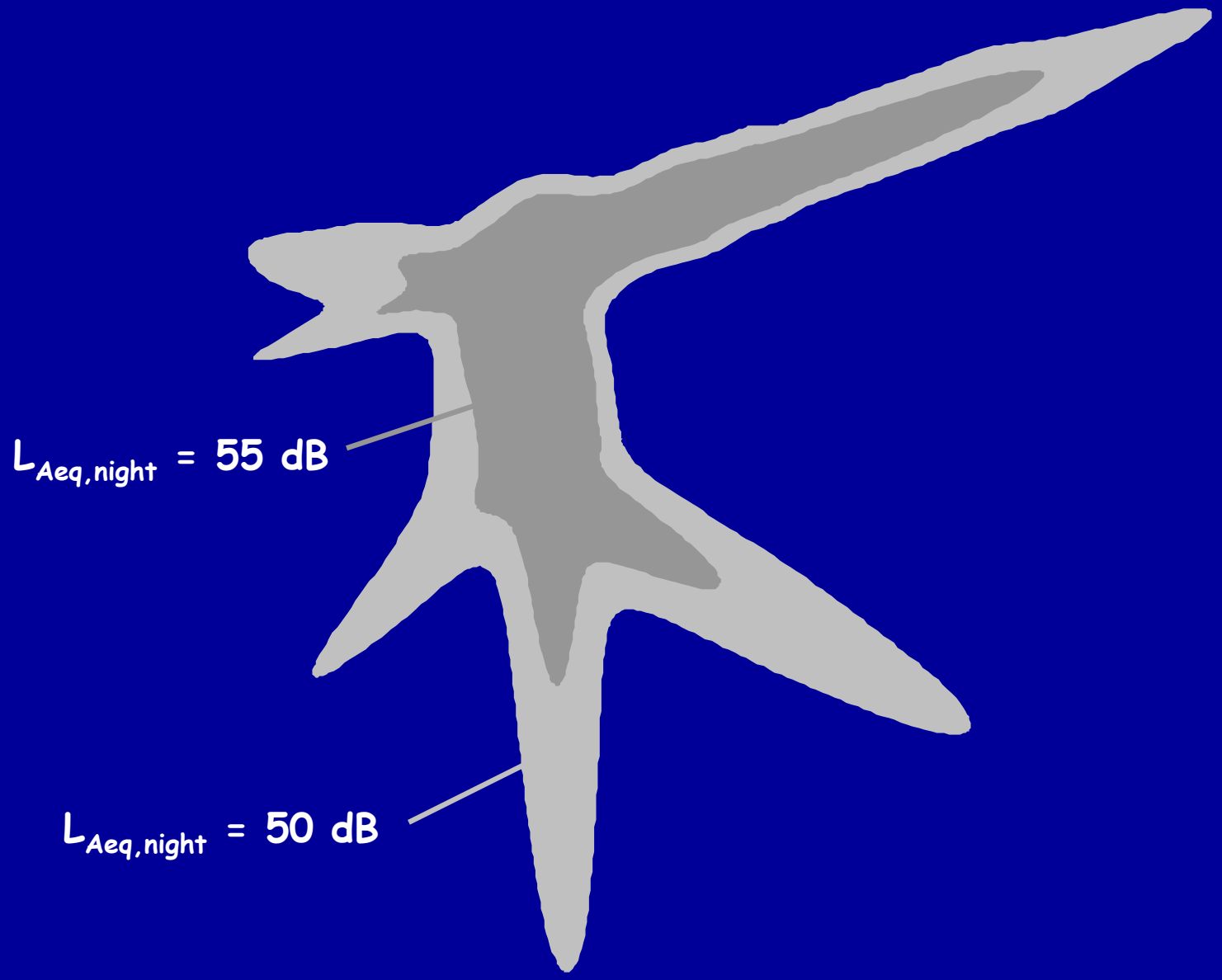
- they unequivocally indicate awakening
  (behavioral awakenings underestimate and
  body movements overestimate the number of awakenings)

Why event-related awakenings ?

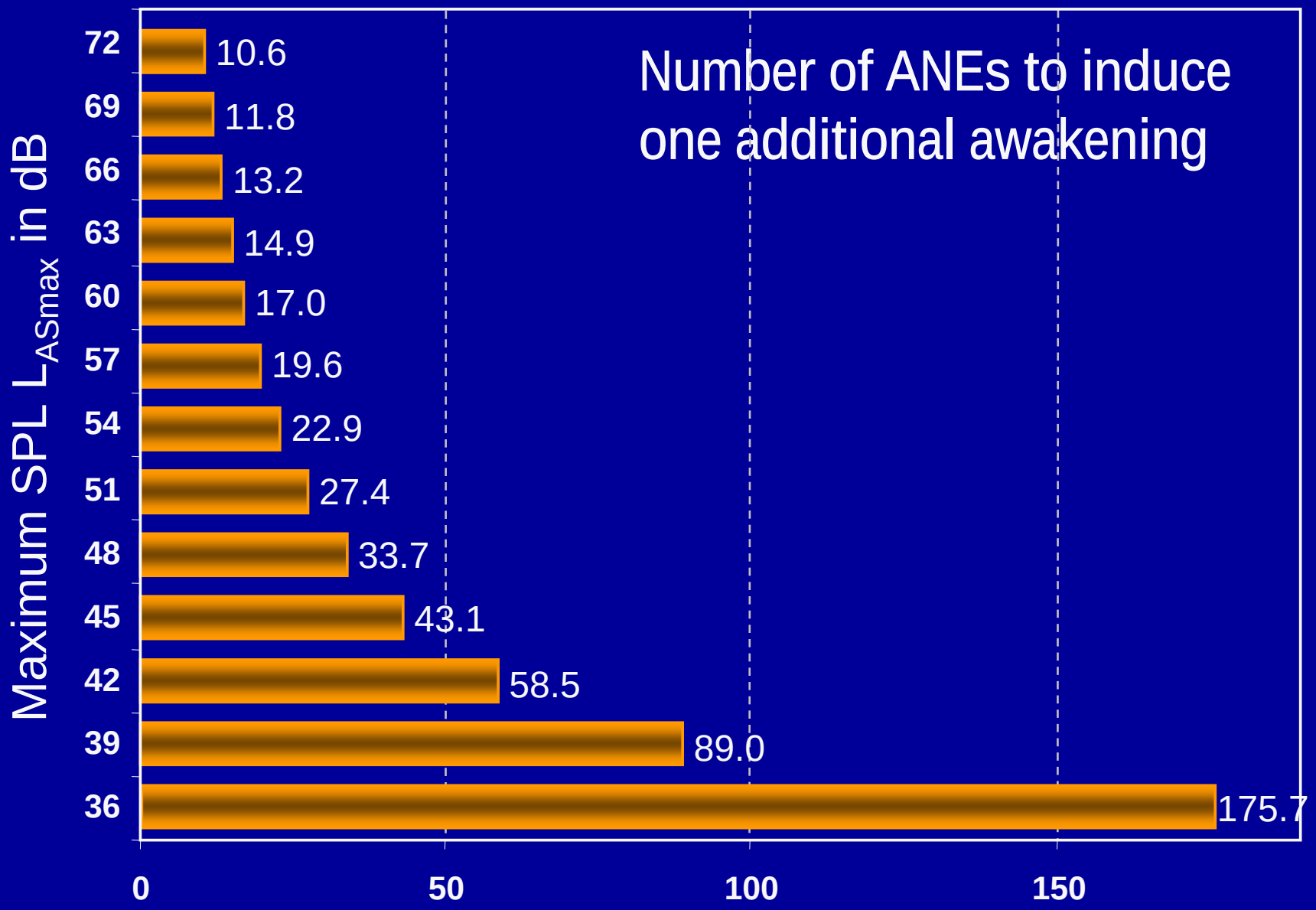
- reliable dose-response curves
- systematically related to distinct acoustic features
  -> derive technical/operational preventive measures

	Sleep disturbances			After-effects		
	Event-related					
	cardiac arousals	wake-up probability	Sleep structure	Subj sleep quality	Perfor-mance	Chronic diseases
Acoustic features	Single noises		Integrated noise metrics (L_{Aeq}/L_{night})			
– Type of noise	++	++	+	-	?	+/-
– Maximum level	++	++				
– Rise time	++	++	+	+	+	+/-
– Duration of noise	-	++				
– Duration of pause	-	++				
Situational factors						
– Elapsed sleep time	++	++				
– Sleep stage prior	++	++				
Individual factors						
– Gender	-	-	-	-	-	
– Age	-	+	+	+/-	+/-	
– Noise sensitivity	-	-	-	-	-	

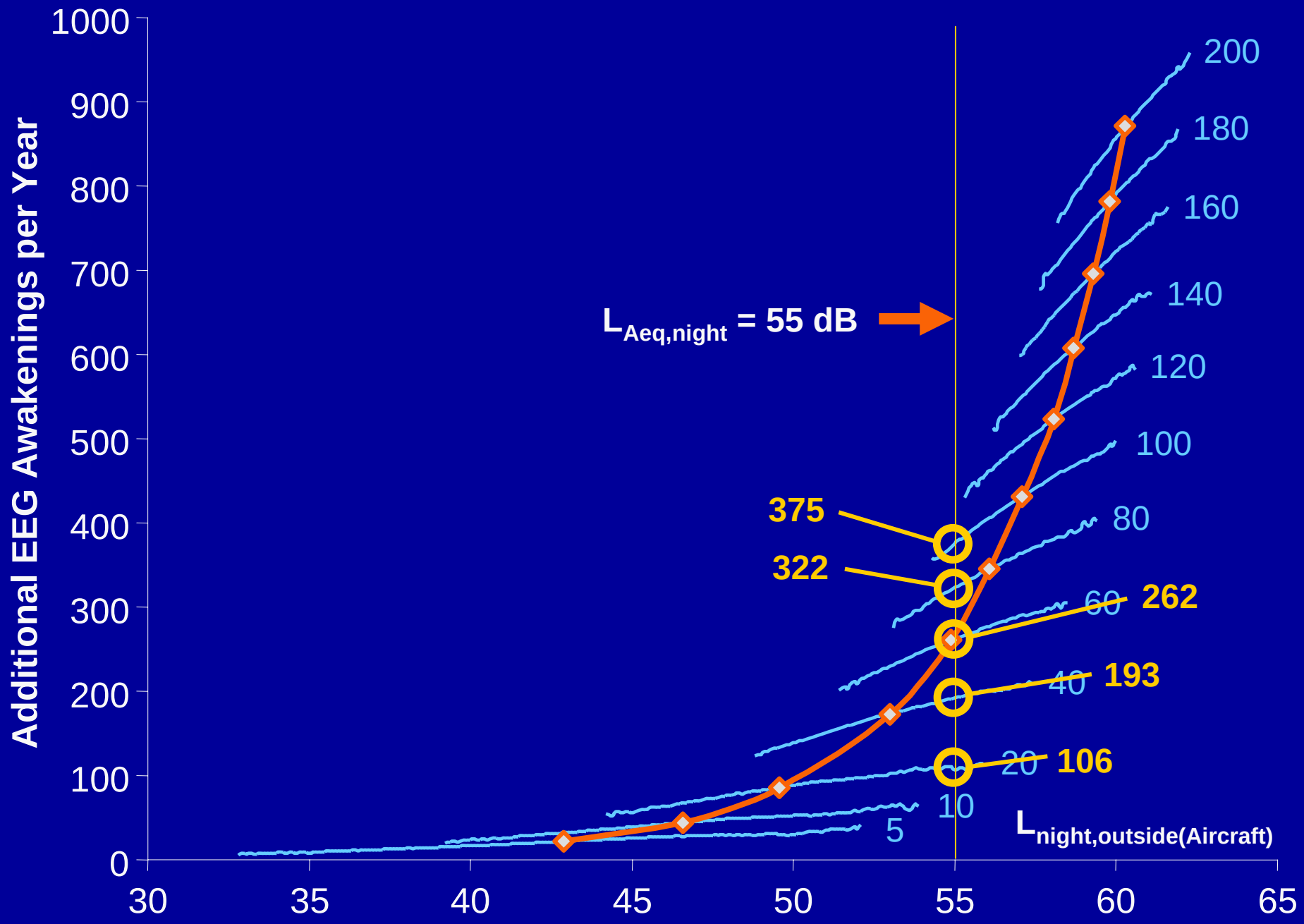
Protection areas defined by L_{Aeq} = 50/55 dB
(Frankfurt Airport, 1997)



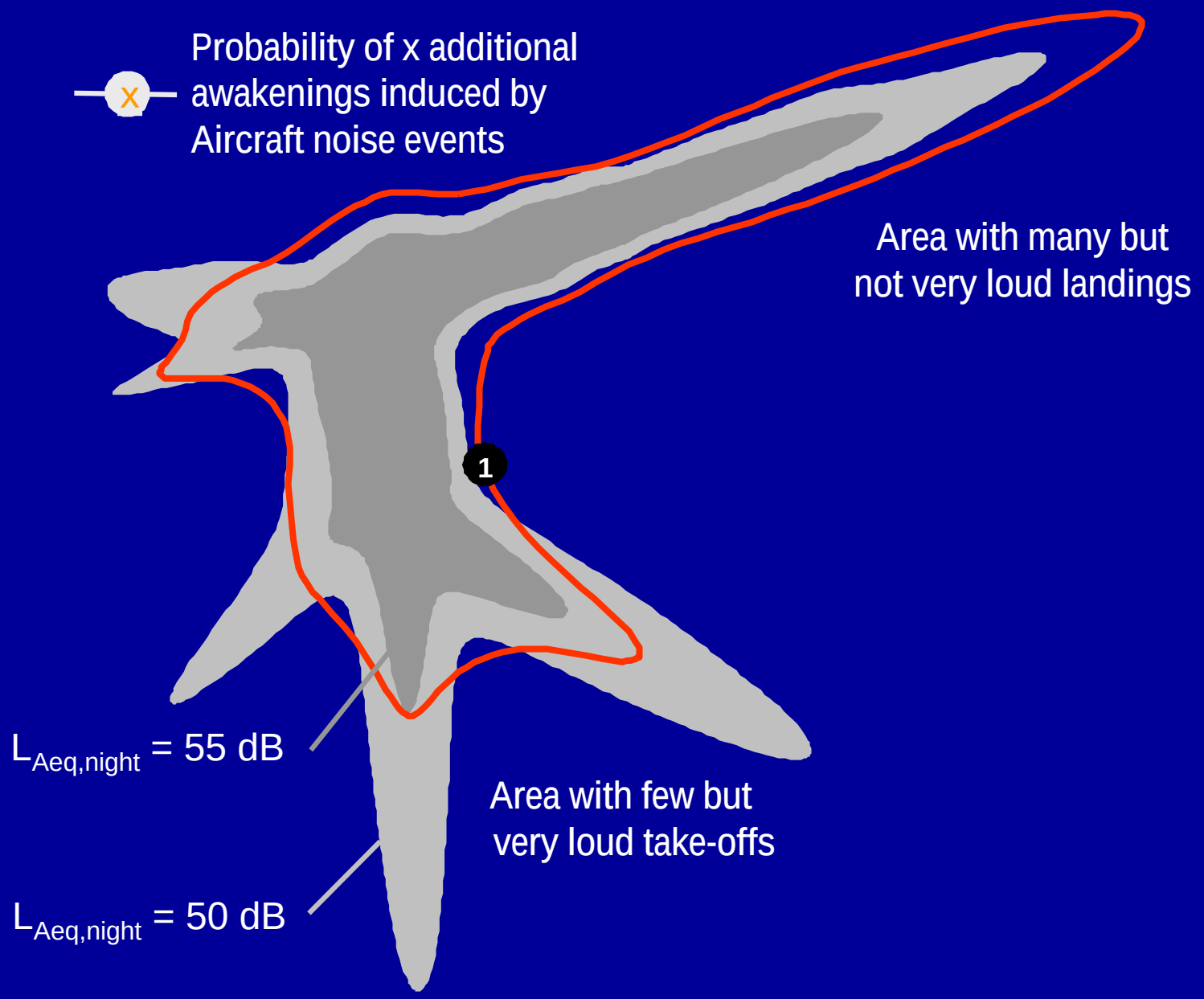
Evaluation & Protection – acoustic criteria



Evaluation & Protection – acoustic criteria



Protection areas L_{Aeq} vs probability of awakenings



Prevention of sleep disturbances by aircraft

P R O T E C T I O N C O N C E P T

Allow on average less than one awakening additionally induced by aircraft noise.

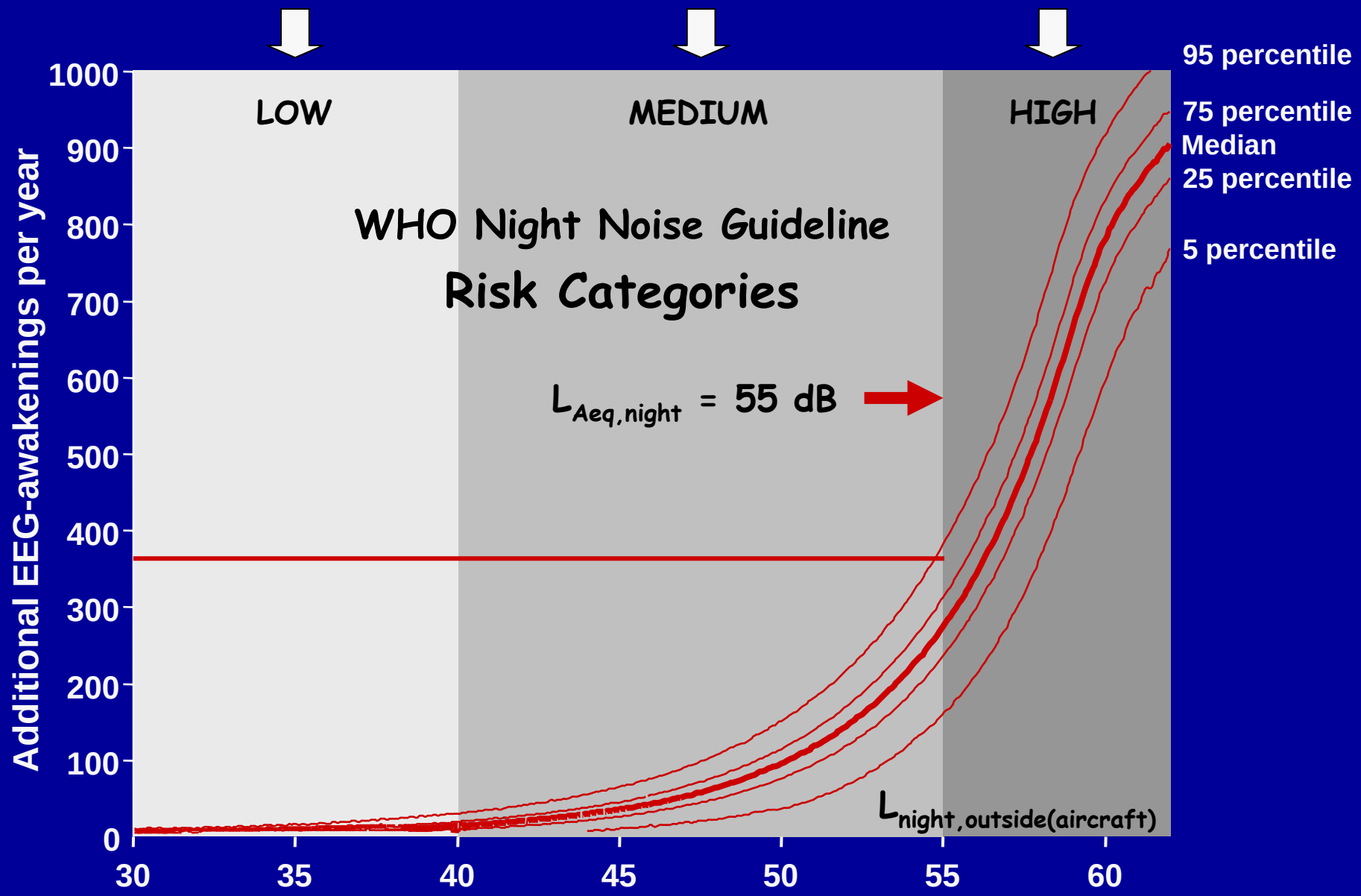
< 1 AWR

+ 4.2 %

more awakenings

Mathias Basner

Evaluation & Protection – acoustic criteria



Prevention of sleep disturbances by aircraft

P R O T E C T I O N C O N C E P T

Avoid interference with the process of falling asleep again.

1.4 dB malus
(2nd half of night)

Allow on average less than one awakening additionally induced by aircraft noise.

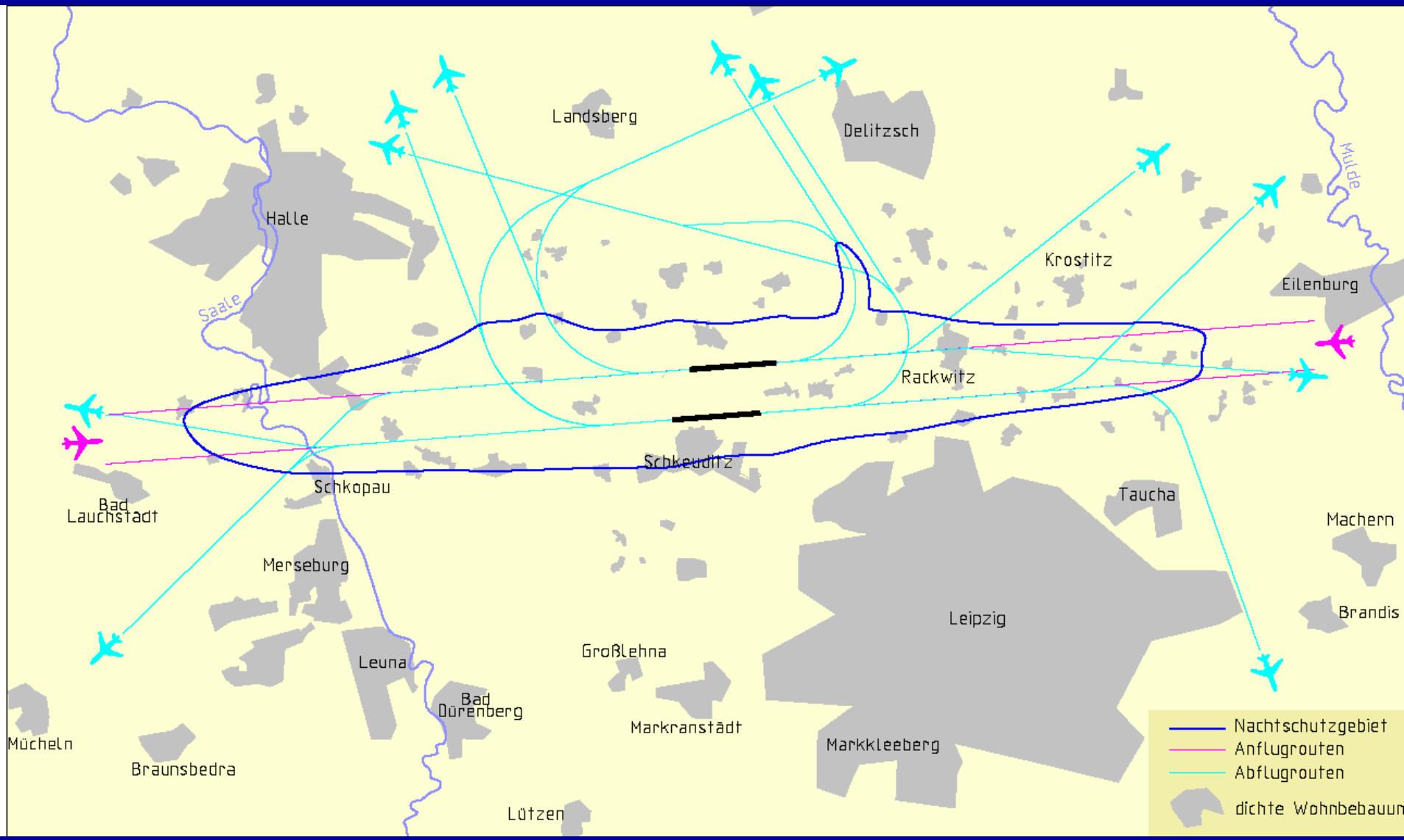
< 1 AWR

Avoid awakenings that are recalled in the morning.

1 x 65 dB_{inside}
(100%-rule)

Mathias Basner

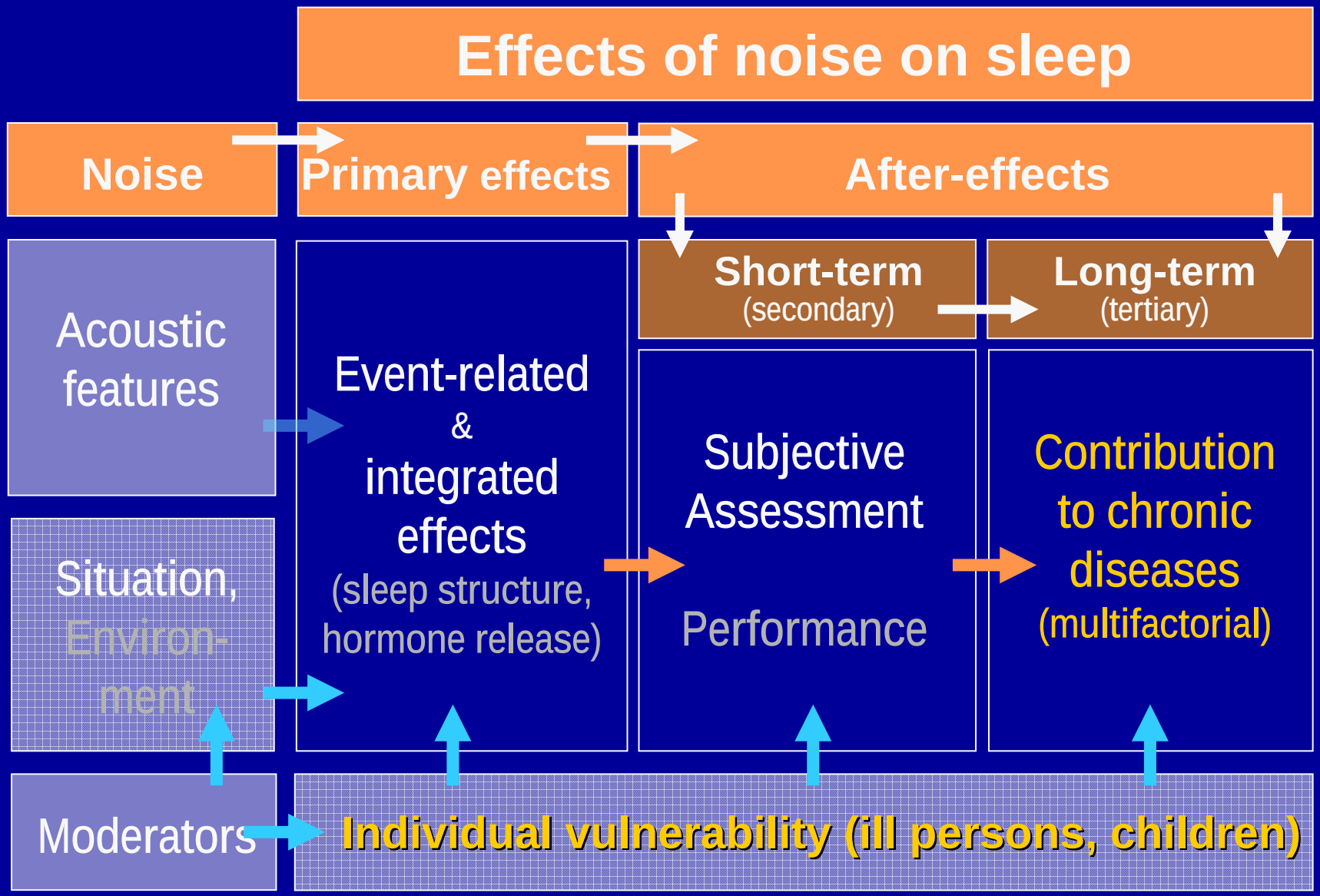
Protection areas Airport Leipzig/Halle 2015



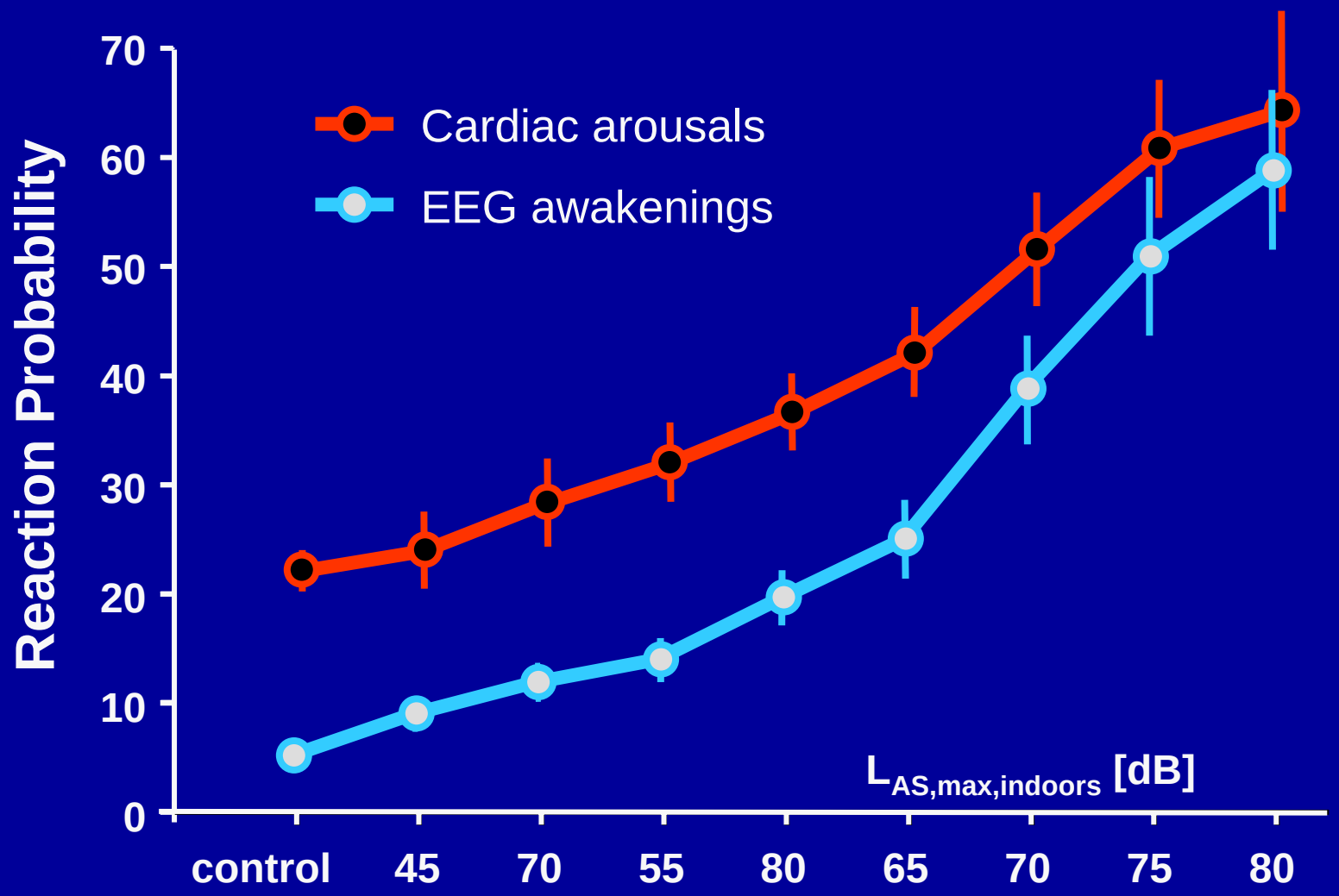
Mathias Basner

Future research

Hypothesis: noise-induced sleep disturbances

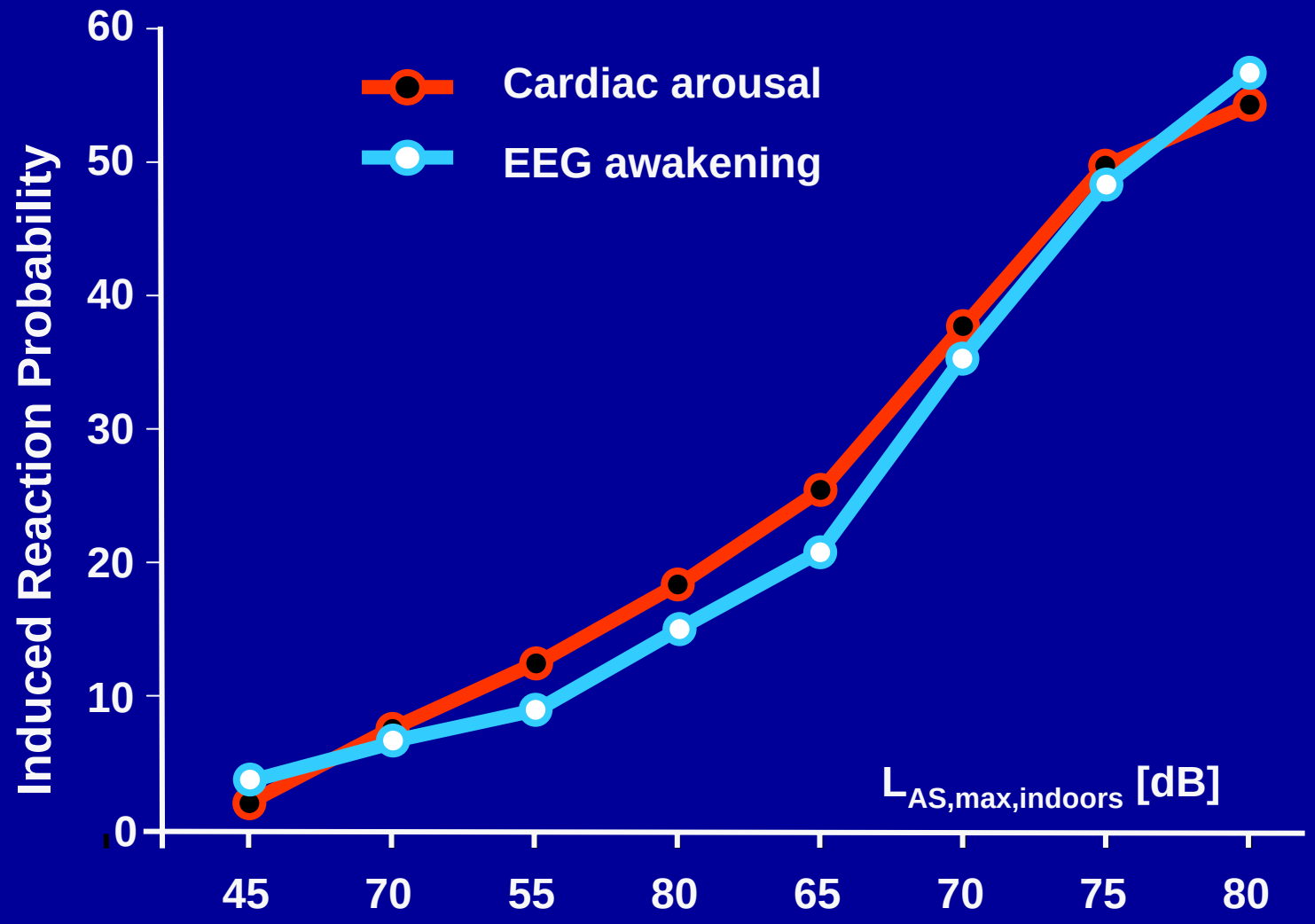


Event-related awakenings
Dose-response curves

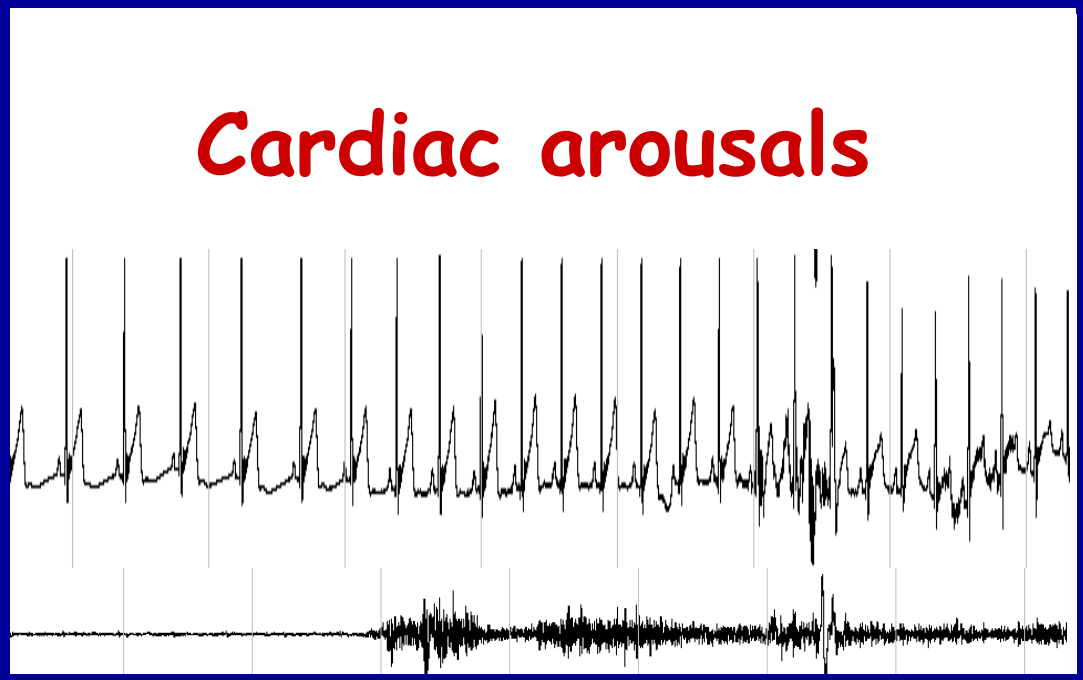


A

Event-related awakenings
Dose-response curves
(spontaneous alterations eliminated)



Sleep recording – sleep structure



Reliable
Inexpensive
Self-application
Extended field studies

Mathias Basner

FAA – Development of a research roadmap

Mathias Basner (German Aerospace Center)
Patricia Davies (Purdue University)
Jim Fields (Consultant)
Laurie Fisher (FAA)
Barbara Griefahn (IfADo)
Raquel Girvin (FAA)
Mehmet Marsan (FAA)
Sarah McQuire (Purdue University)
Nick Miller (HMMH)

FAA – workshop
August 27 2009

IfADo

DLR

Thank You for Your Attention