

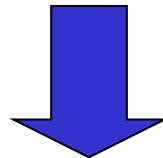
An Introduction to Research on Traffic Noise Effects on Sleep

FAA Workshop, 10 Dec 2009, Washington, D.C.

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Barbara Griefahn**

Noise and Sleep

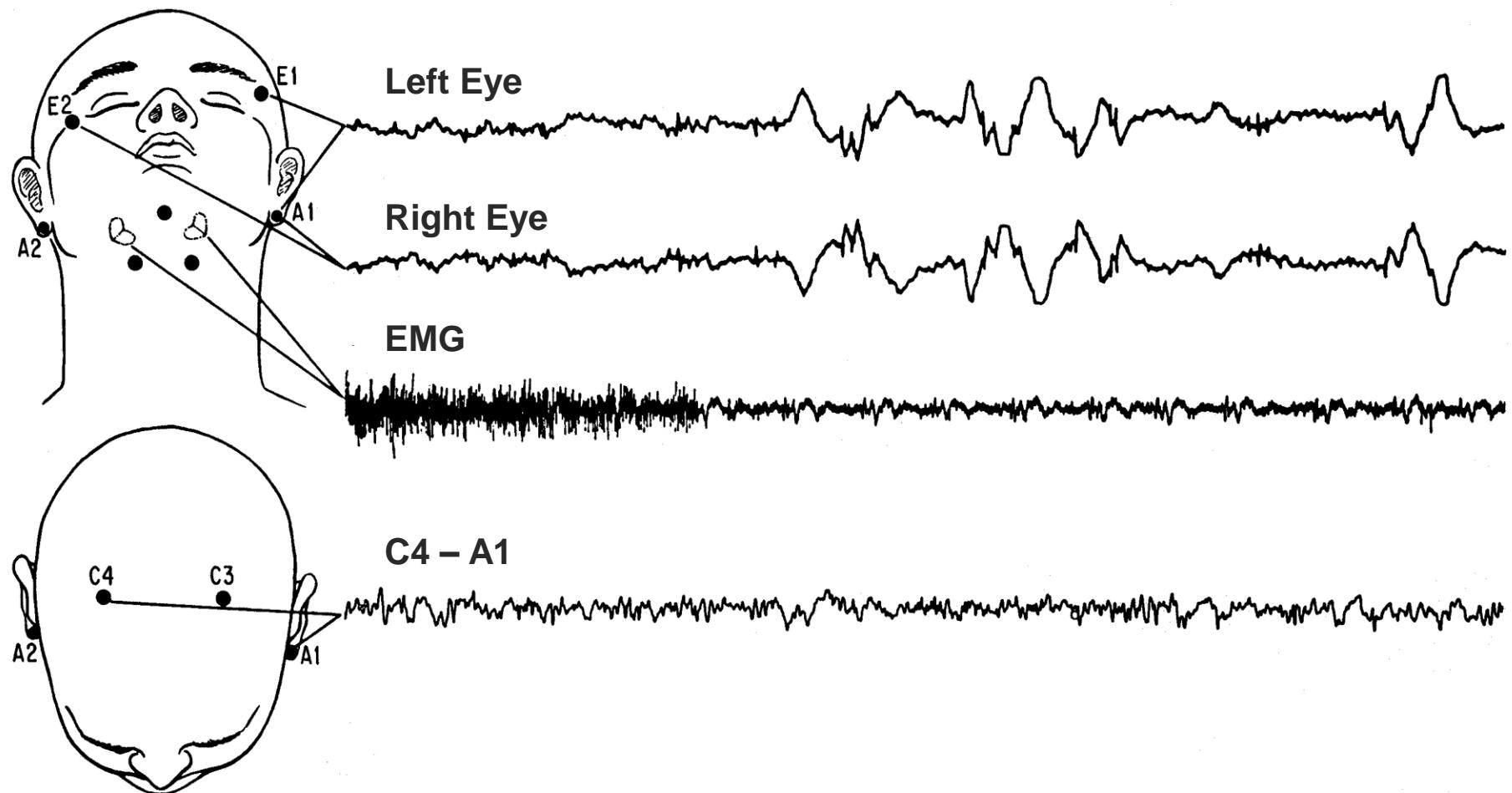
- Undisturbed sleep of sufficient length is essential for performance, well-being and health.
- The organism perceives, evaluates and reacts to environmental noise even while asleep.



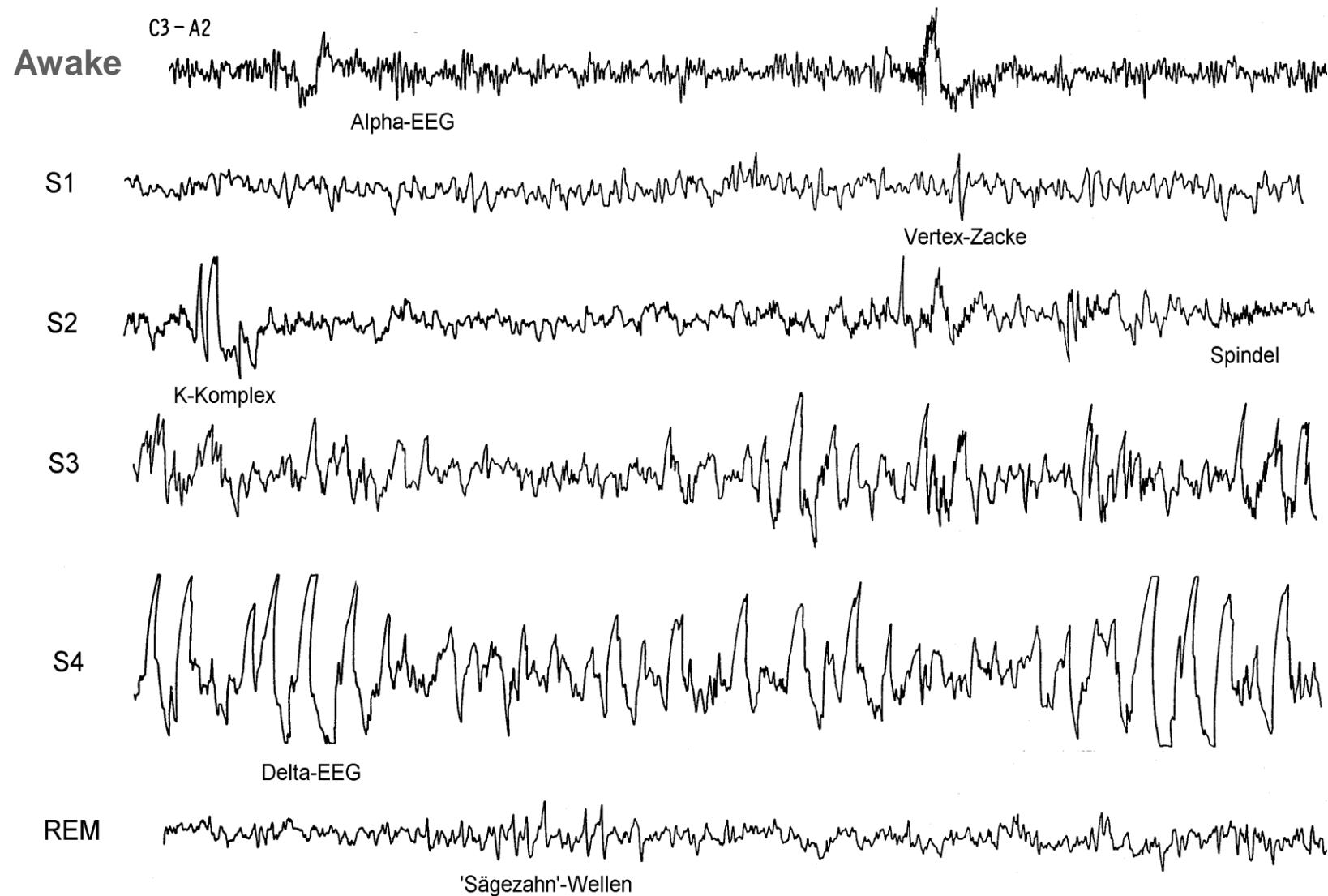
- Environmental noise may disturb or fragment sleep, impair recuperation, and therefore also impair performance, well-being, and health.
- Recent epidemiological studies stress the importance of nighttime aircraft noise exposure for public health.

Measuring Sleep

Signals for Sleep Stage Classification

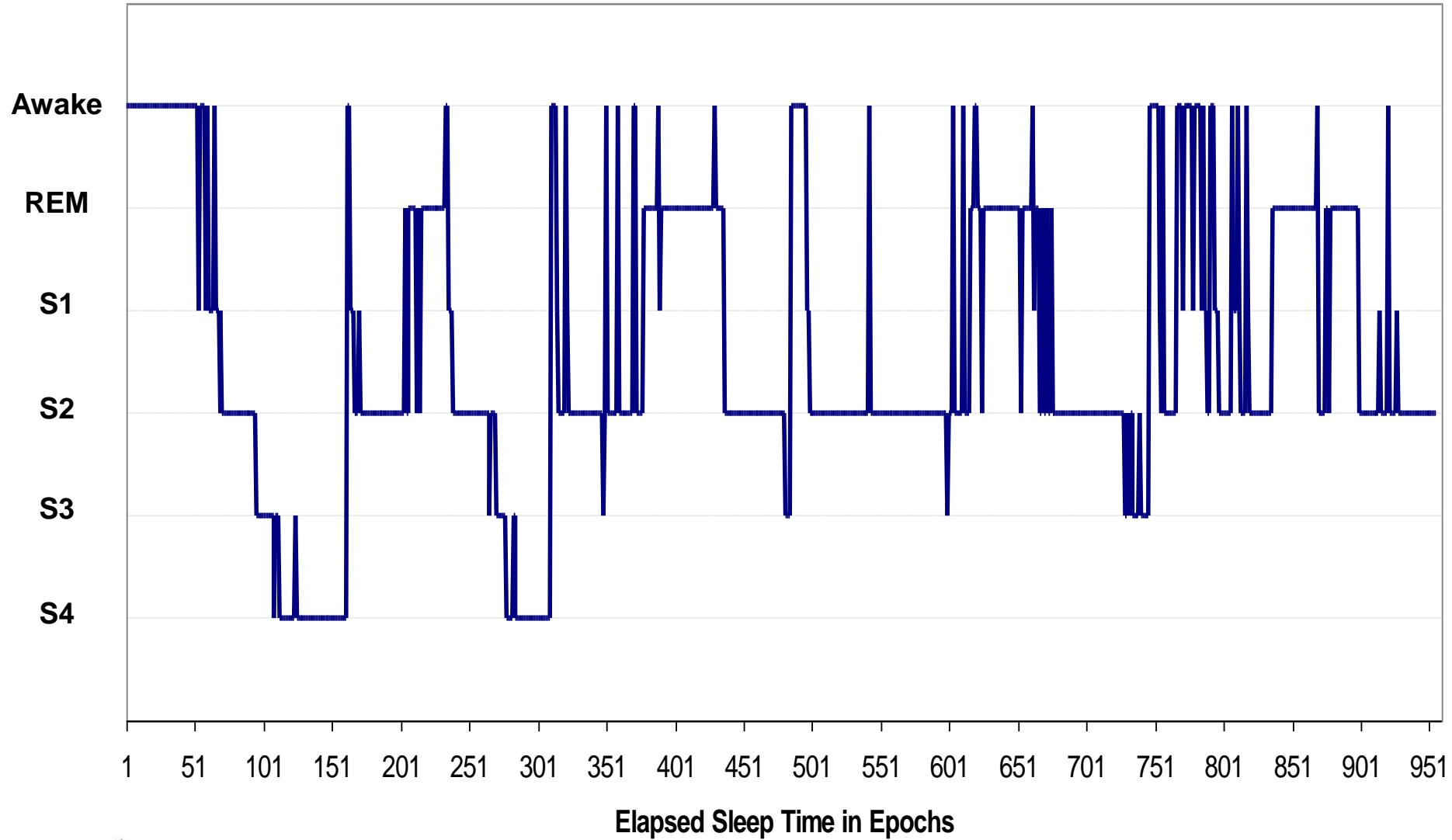


Sleep Stage Classification (R&K)

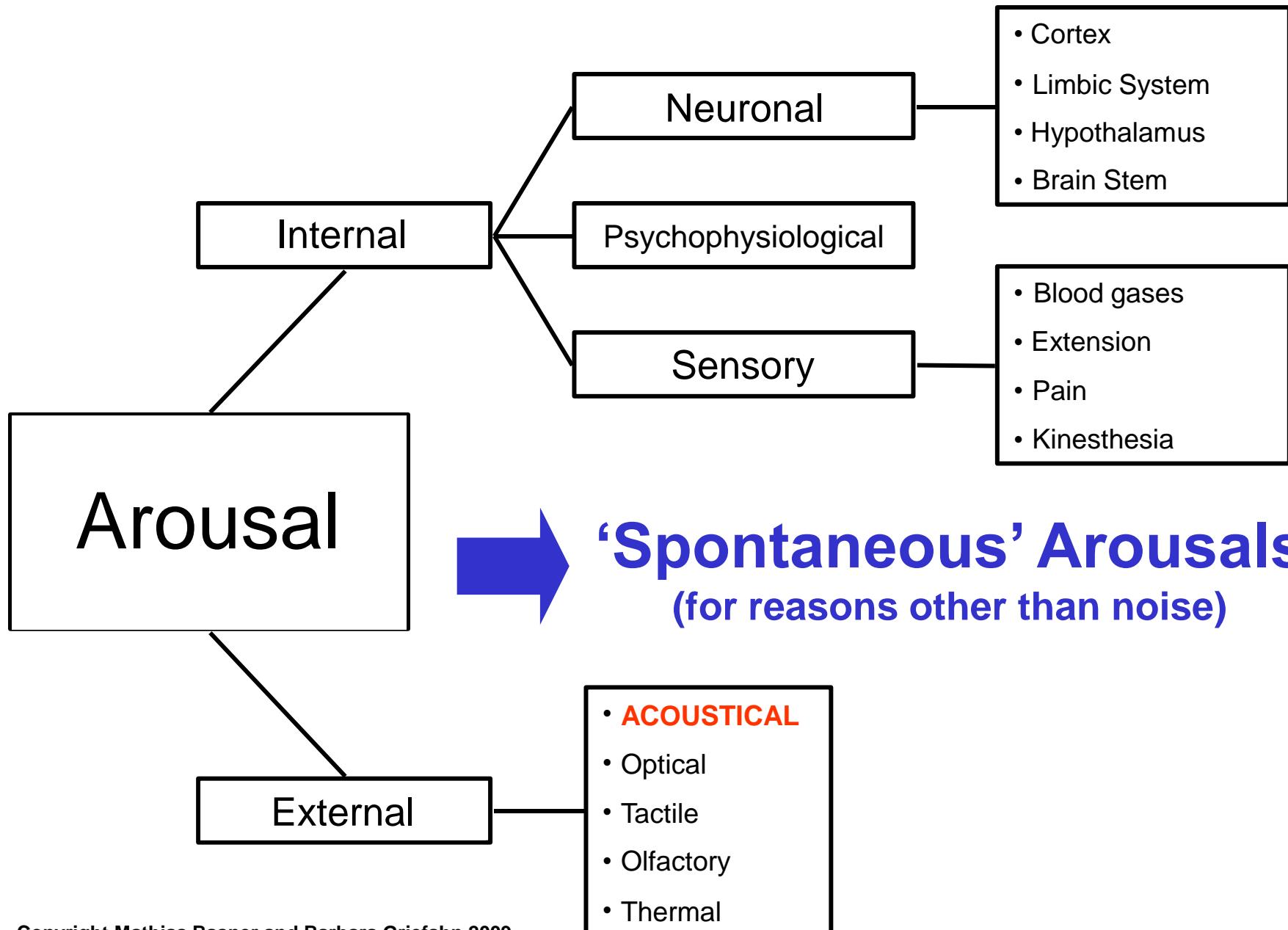


Rechtschaffen et al. 1968, Iber et al. 2007

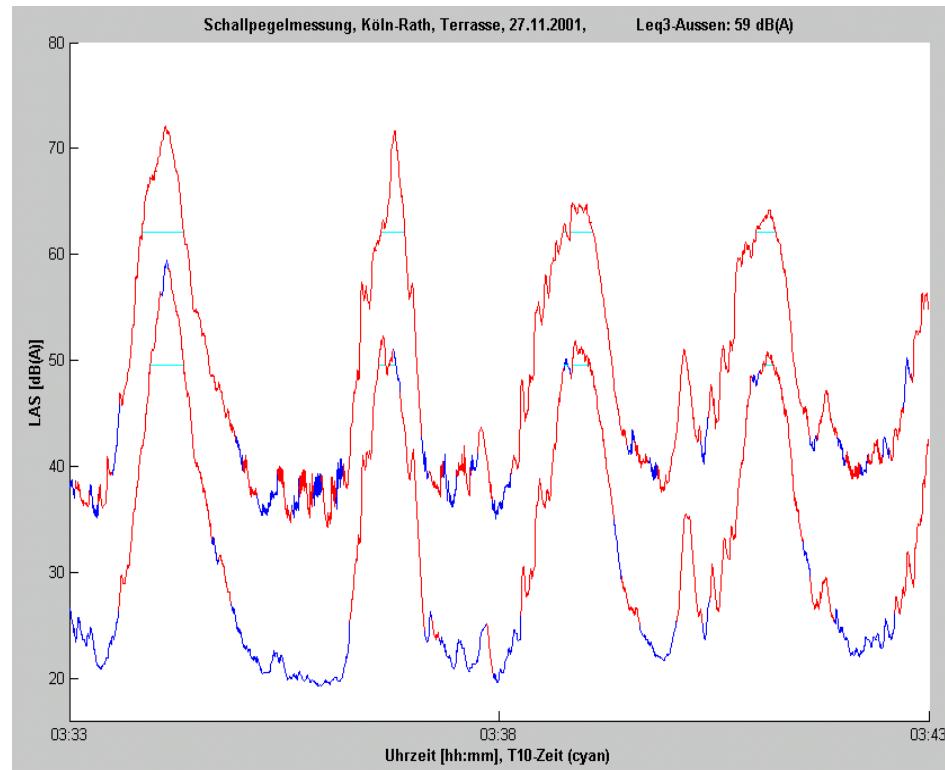
Hypnogram of a Night without Traffic Noise



Noise-induced arousal from sleep are non-specific



Noise and Sleep



- Noise exposure during the night is mostly *intermittent* due to low traffic densities.
- The sleeper primarily reacts to single noise events.

Noise and Sleep

Individual Moderators

- Noise Sensitivity
- Age...

Acoustic Properties of Single Noise Events

- Maximum SPL
- Rise Time...

Situational Moderators

- Current Sleep Stage
- Elapsed Sleep Time...

Physiologic Reactions Related to Single Noise Events

- Cerebral and Autonomic Arousal
- Sleep Stage Changes, Awakenings, Body Movements etc.

Whole Night: Disturbance/Fragmentation of Sleep Structure

- Quantitatively: Decreased Sleep Duration
- Qualitatively: Deep Sleep ↓, REM Sleep ↓, Awake ↑

Short-term Effects

- Performance ↓
- Sleepiness ↑

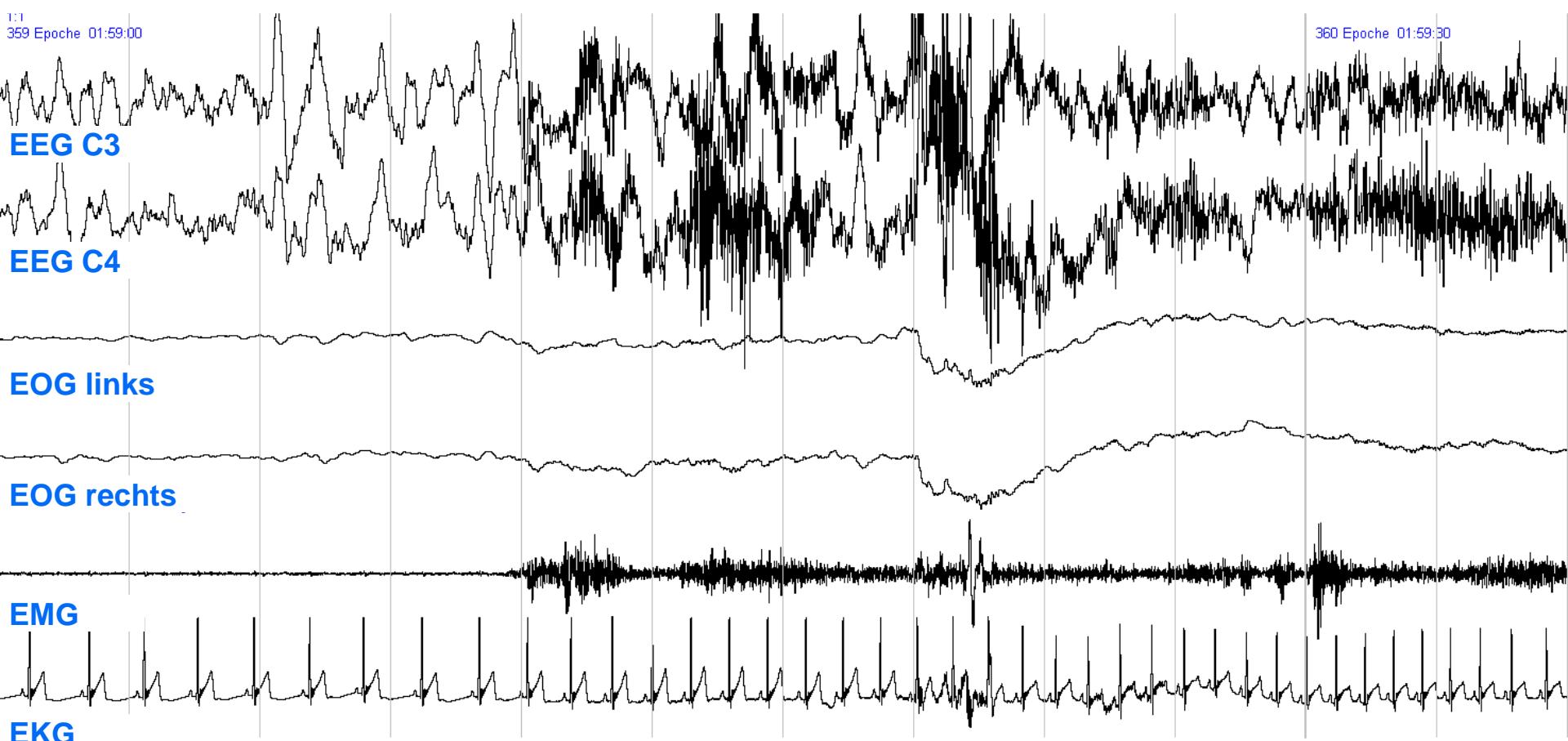
Long-term Effects

- High Blood Pressure ↑
- Myocardial Infarction ↑

Awakening from Sleep

Wake pattern for at least 15 seconds

ca. 20-25 per night



36 s printed

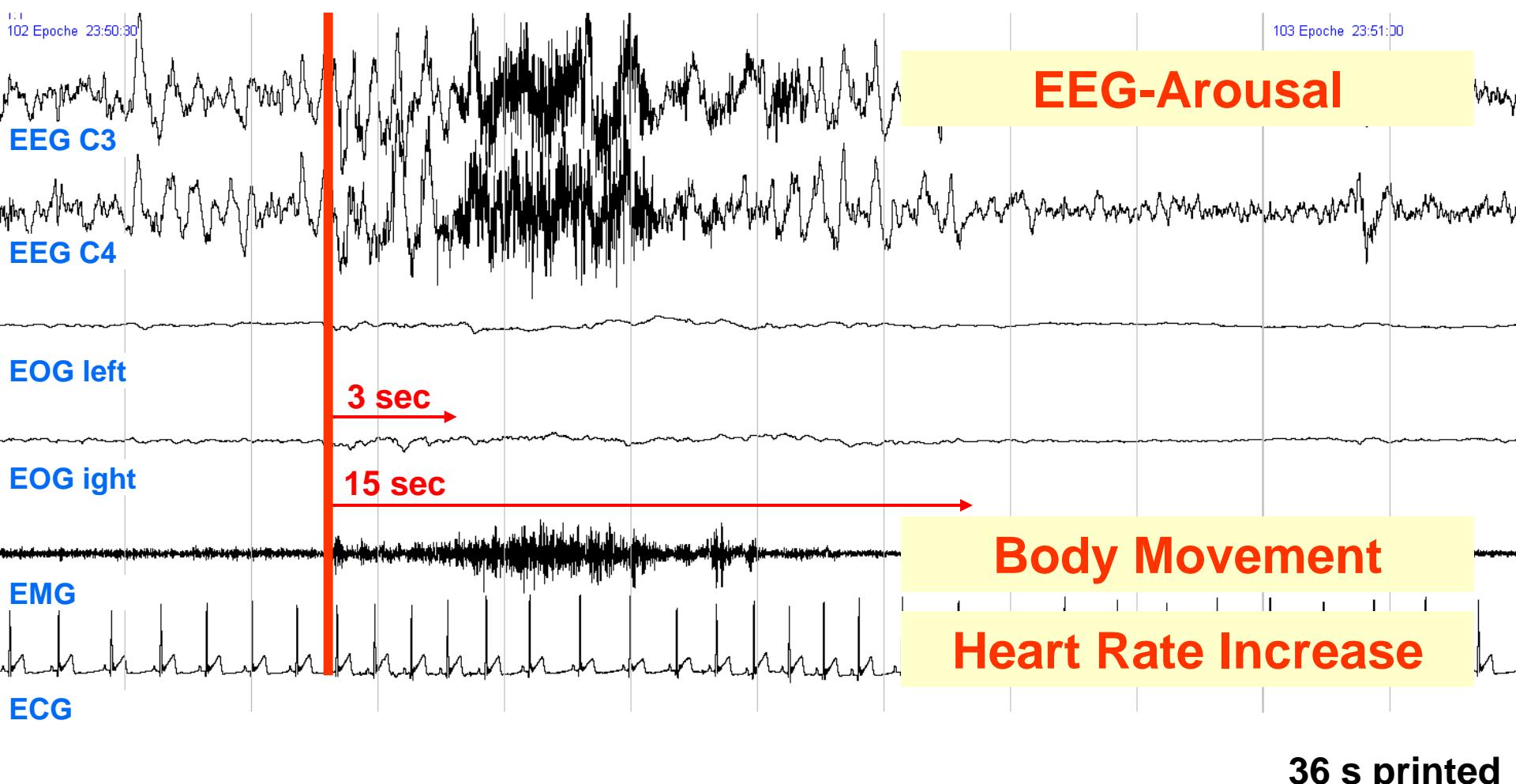


EEG-Arousal

Sleep 1992 15(2): 173-184

ca. 100 per night

Linked Reactions



Arousal Degree

Maximum Arousal

~1-5 per night

Long Awakenings (>1 min) with Reoccurrence of Consciousness

Methods

Push Button,
Actimetry,
Polysomnography

~23 per night

Short Awakenings (>15 s)
with Body Movements

Actimetry,
Polysomnography

~120 per night

Short Awakenings (>15 s)
w/o Body Movements

Polysomnography

~100 per night

Sleep Stage Changes

Polysomnography

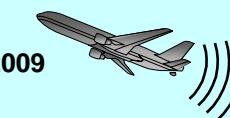
Short (> 3s) EEG Accelerations
with or w/o Sleep Stage Changes

Polysomnography

Minimum Arousal



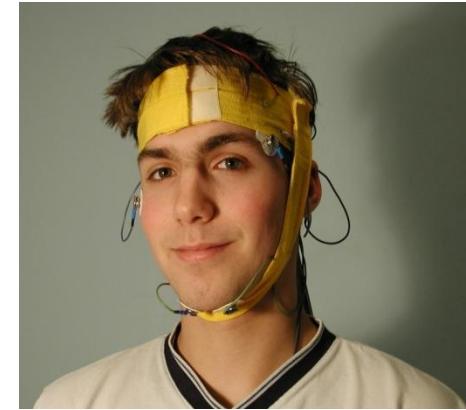
Stimulation of ARAS through internal or external stimuli



Polysomnography

Pros

- Gold Standard for the evaluation of sleep structure and the degree of sleep fragmentation
- Well standardized
- Very sensitive (detection of subtle physiological changes)



Cons

- Electrodes somewhat invasive → influence sleep
- Trained personnel needed for electrode attachment and data analysis → expensive
- High inter-rater variability in sleep stage classification

Actigraphy

Pros

- Easy to use → inexpensive
- Less invasive than polysomnography
- Sensitive for picking up body movements



Cons

- Low degree of standardization
(hardware, algorithms for analysis)
- Misclassifications (wake → sleep and sleep → wake)

Signaled Awakenings (Push Button)

Pros

- Easy to use → very inexpensive
- Non-invasive
- High specificity (i.e. few spontaneous signaled awakenings)

Cons

- Low degree of standardization (instructions!)
- Low sensitivity
- Sleep may be altered by demanding active cooperation
- Motivation to push the button influences results

Questionnaires

Pros

- Easy to use → very inexpensive
- Non-invasive
- Positive subjective assessment of sleep quality and quantity
primary goal of noise mitigation policy

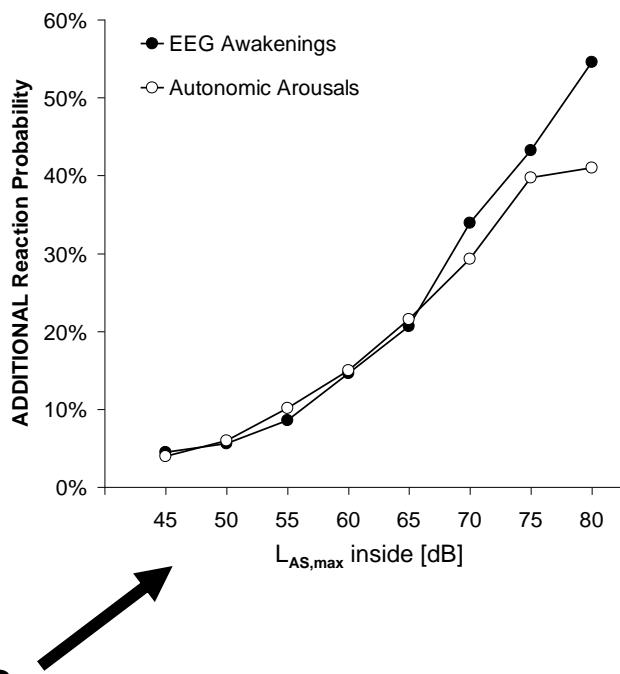
Cons

- Subjects are not aware of their surroundings during most of the night → relevant noise-induced activations may be missed
- Substantial discrepancies between subjective and objective evaluation of sleep possible

Electrocardiogram (ECG)

Pros

- Easy to use → inexpensive
- Less invasive than polysomnography
- Automatic algorithm for data analysis
→ objective and not time consuming
- Good agreement with EEG awakenings
- Repeated autonomic arousals may be reason for long-term health effects



Cons

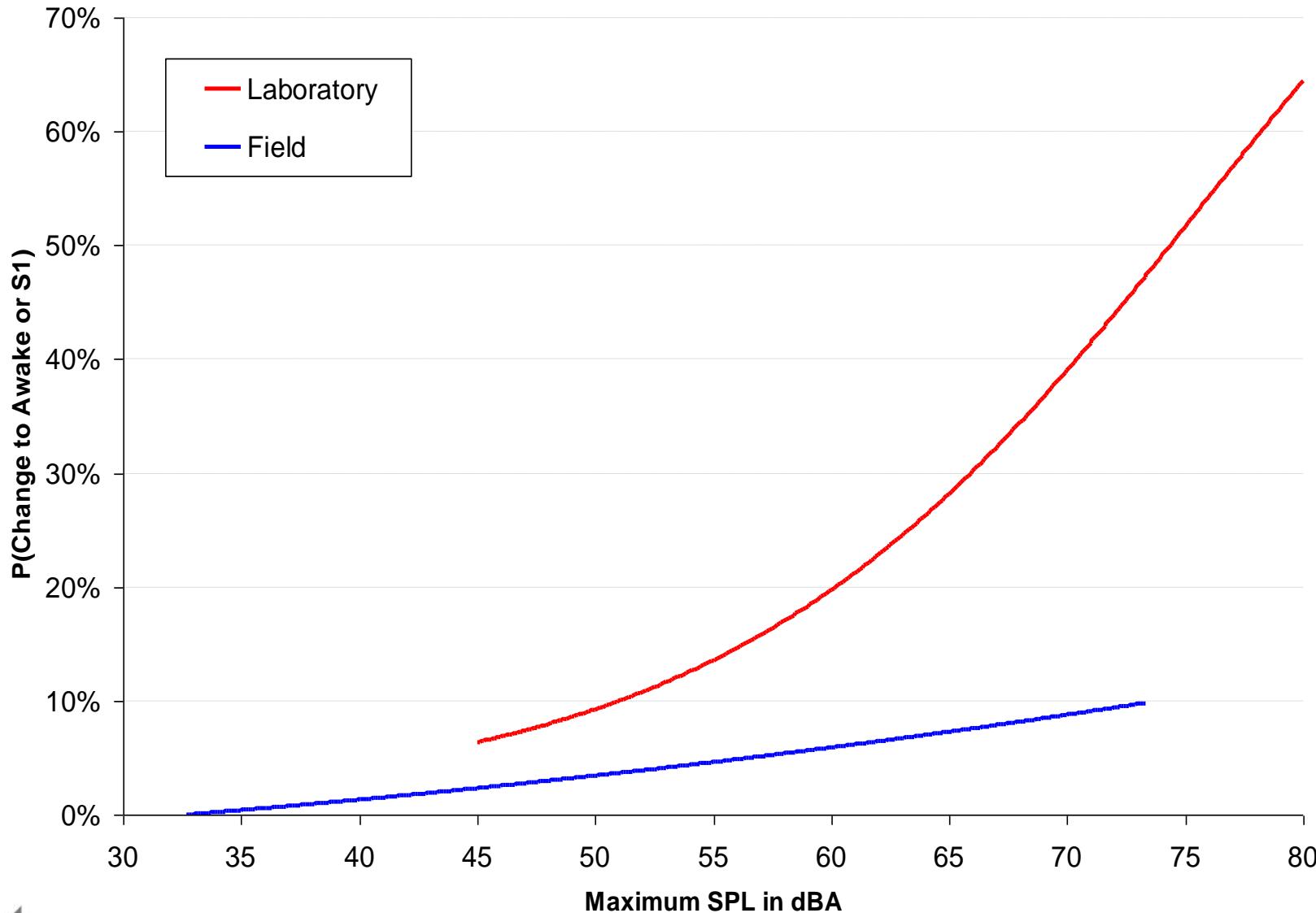
- Not yet standardized
- Further validation needed

Basner et al., SLEEP 30(10), 2007

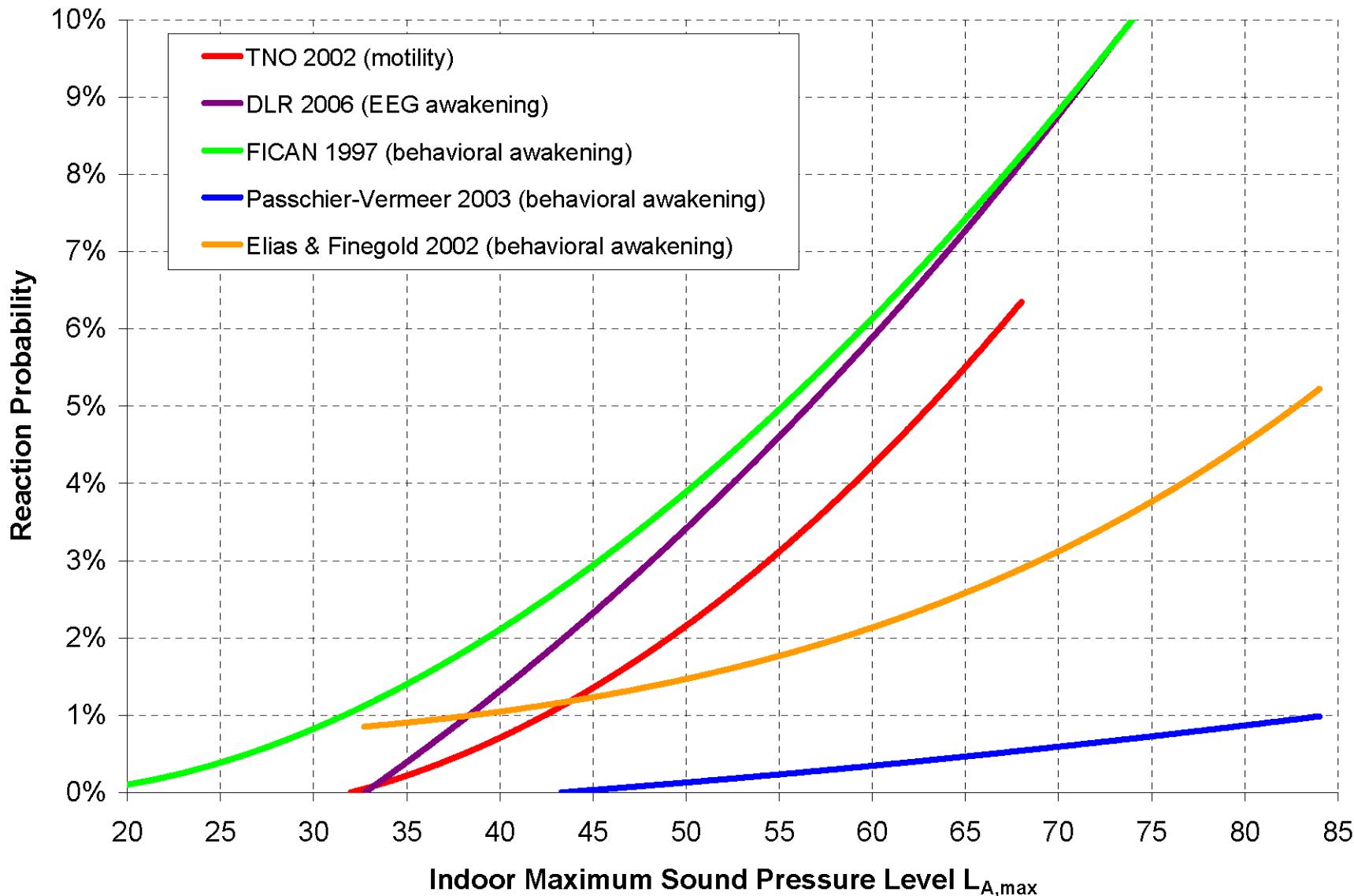
Basner et al., Physiol. Meas. 29(9), 2008

Laboratory and Field Study

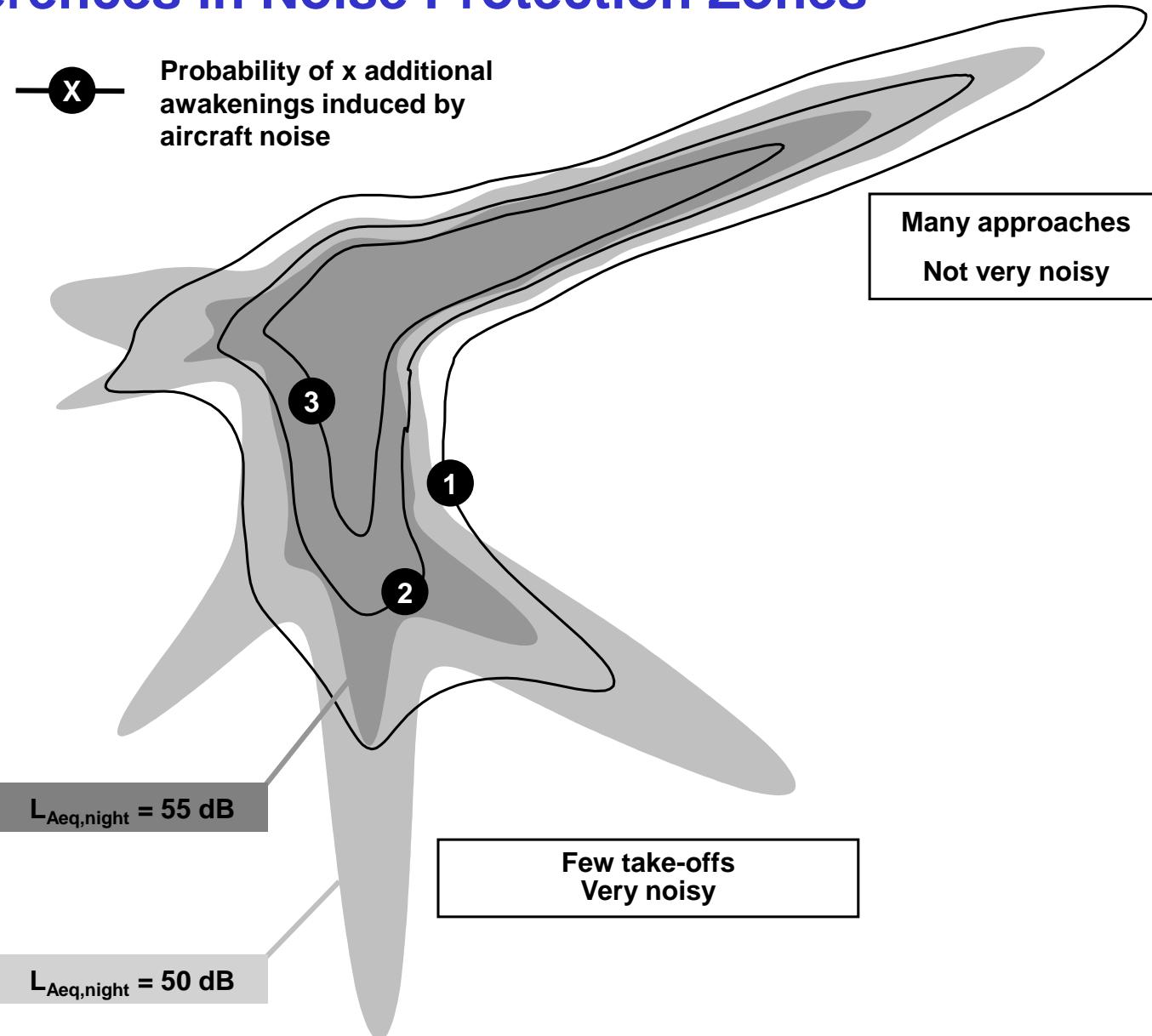
Comparison of Dose-Response Relationships



Exposure-Response Relationships



Differences in Noise Protection Zones



Differences in Noise Sensitivity

64 x 65 dB

Awake

REM

S1

S2

S3

S4

B

$P_{AWR} = 88.0\%$

Awake

REM

S1

S2

S3

S4

A

$P_{AWR} = 3.3\%$

23:00

0:00

1:00

2:00

3:00

4:00

5:00

6:00

7:00

Time

Restricted Generalizability of Noise-Effects Studies

- Low response rates
(especially for polysomnography)
- Many exclusion criteria
(children, elderly, diseased)
- How do the non-responders and non-eligible react?

