Noise, nuance and nuisance: an introduction to sound and sleep

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Why do we Sleep?

Some proximate answers

- Without sufficient sleep we experience:
  - Degraded daytime alertness and stamina
  - Impaired memory efficiency
  - Reduced psychomotor performance
  - Emotional dysregulation

  - And we feel wretched…

Why do we Sleep?

An ultimate answer

- As slow, sight-dependent mammals with few natural ‘weapons’ and no natural ‘armour’ – we were very vulnerable at night

- Sleeping kept our genes safe!

What follows from this (1)?

- The need to sleep at night has been hard-wired by natural selection
- If sleep need is not met, physical and psychological consequences are inevitable

What follows from this (2)?

- We are (and we need to be) good judges of variations in our own sleep quality

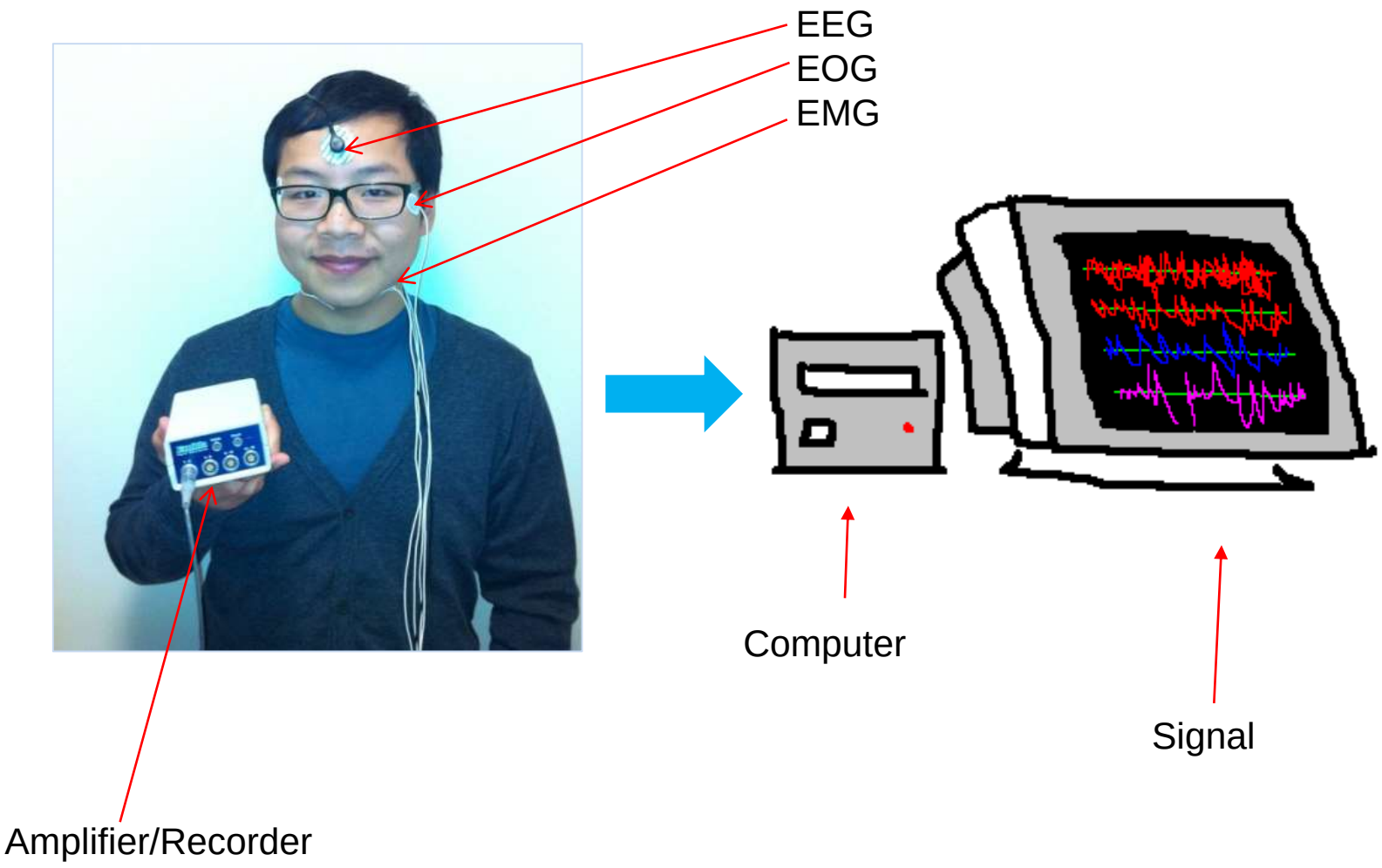
"…due to the fundamental nature of unconsciousness in this state, people are unable to introspect on their sleep state. As such, an individual may surmise the quality of his or her sleep, with descriptions of what his or her presumed sleep was like…"

Michaud et al (2016). Effects of Wind Turbine Noise on Self-Reported and Objective Measures of Sleep. Sleep 39; 1: 97–109

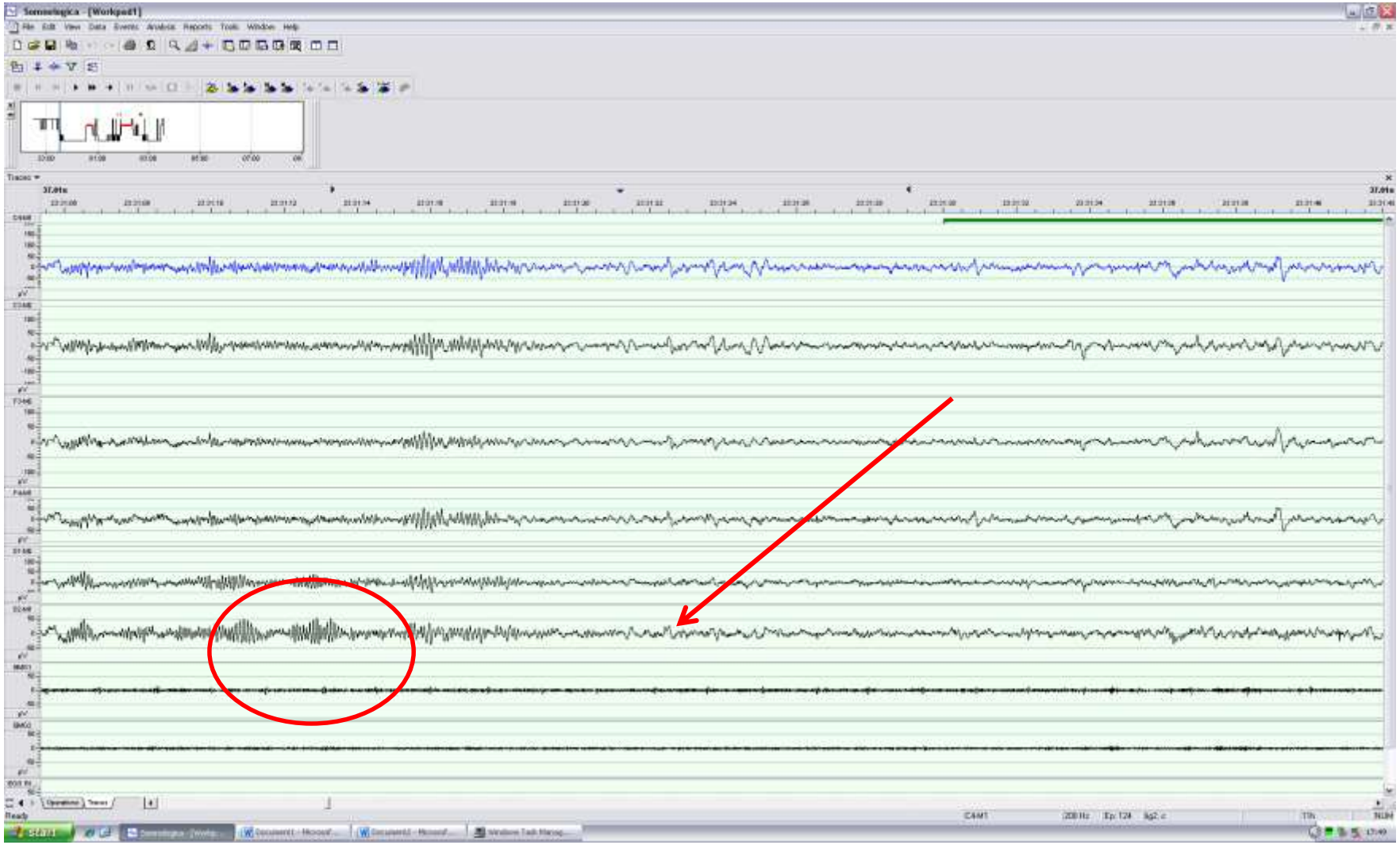
Sleep is controlled by 3 processes

- **Homeostatic Processes**
  - Physiological balance
- **Circadian Processes**
  - Biological clock
- **Psychological Processes**
  - Learning
  - Cognitive Arousal (mental alertness)

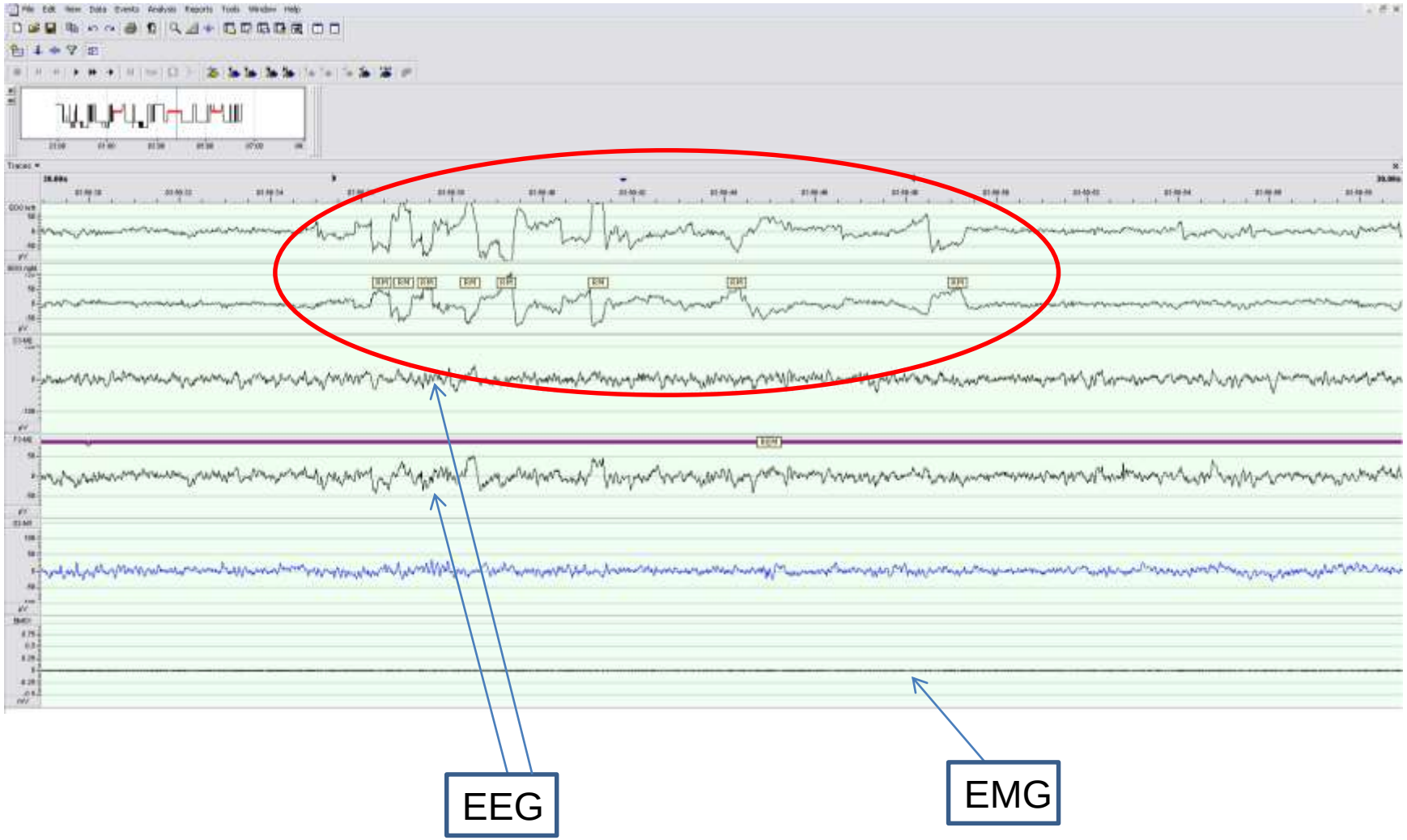
Polysomnography (PSG)



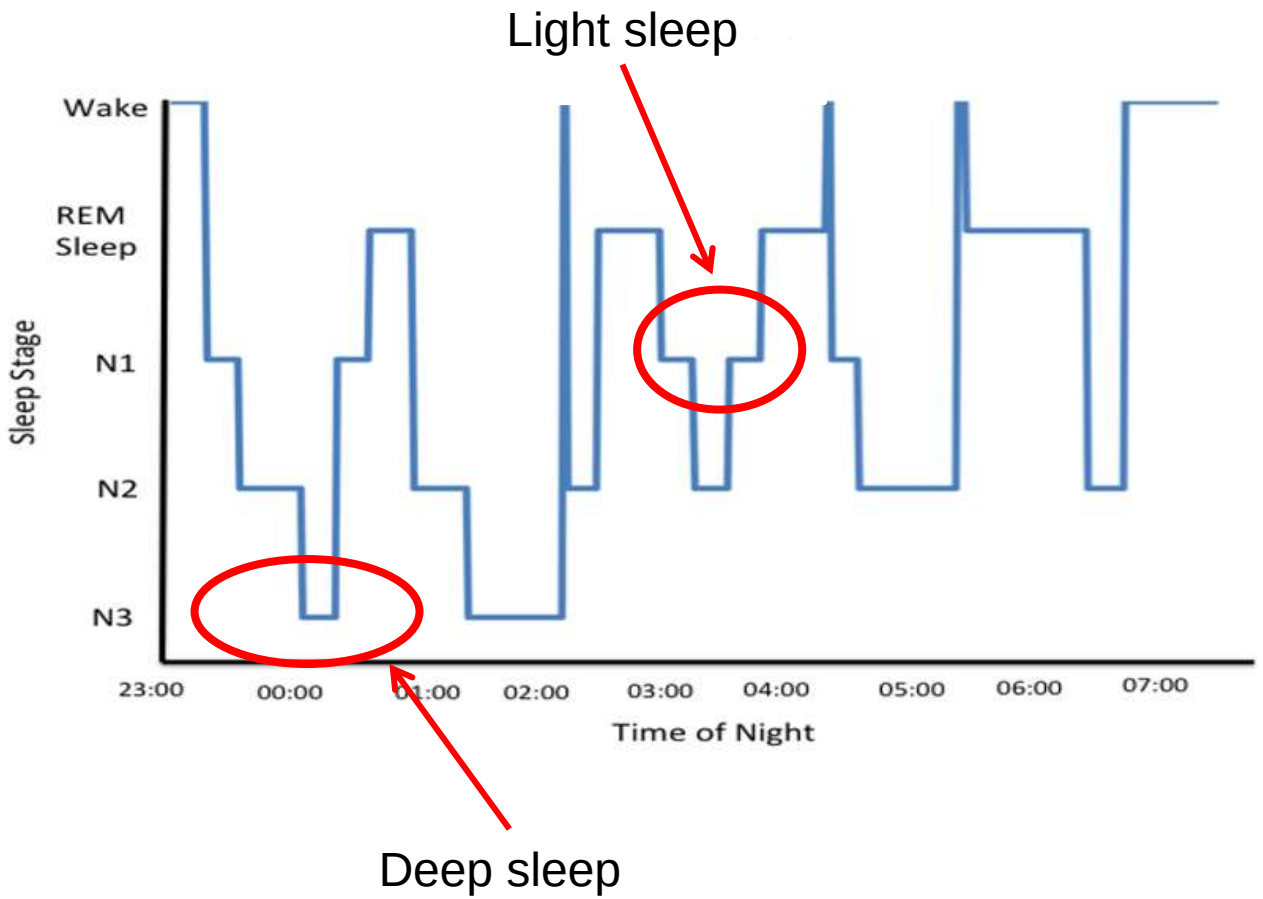
Polysomnogram (PSG): Sleep Onset



Polysomnogram (PSG): REM Sleep



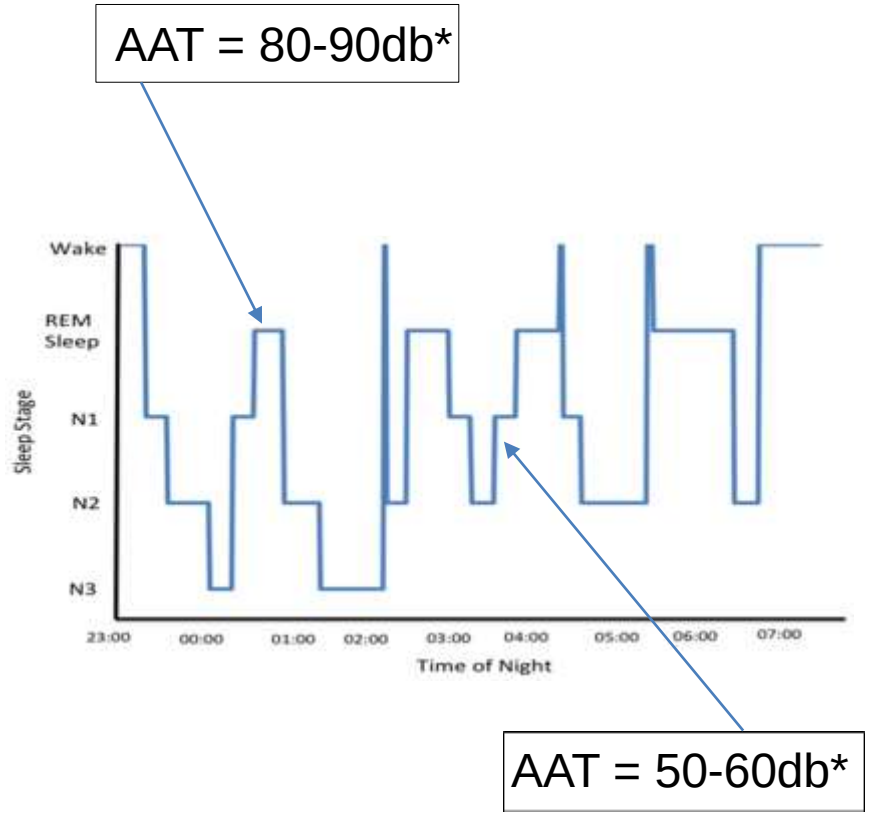
The Hypnogram



Auditory Arousal Threshold

- AAT: the minimum amount of noise required to awaken a sleeping person

- AATs vary depending on the stage of sleep



*1000 Hz, 2 sec tone (Pilon et al, 2012)

Sleep & Sound: Ontogeny

- At 28 weeks – the foetus has well developed sleep-wake cycles
- At 27 weeks - most foetuses respond to 0.25-0.5 kHz tones
- (Background) inter-uterine sound (HR, gut, etc): 60 dB (for 0.1 kHz) <40 dB for 0.2 kHz+)

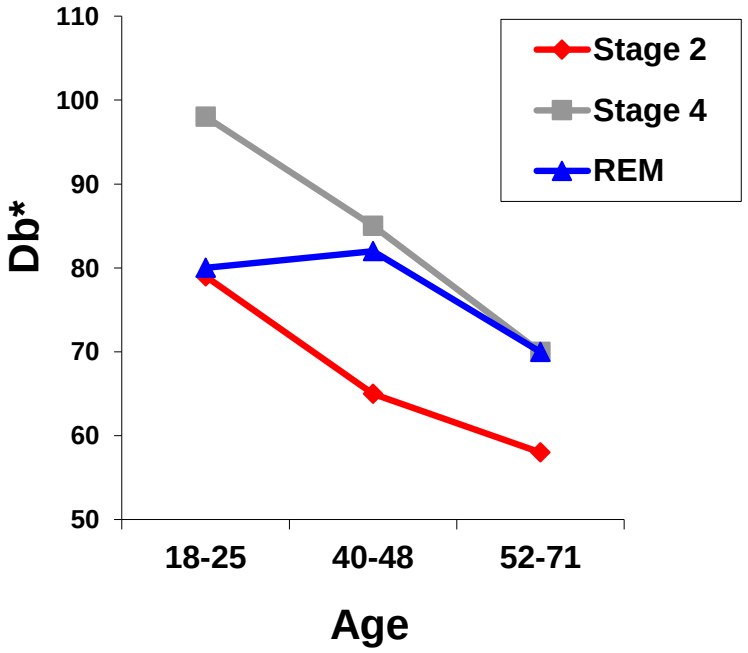
["…$L_{night,outside}$ of 40 dB should be the target of the night noise guideline" (WHO, 2009)]

- 30-35 weeks:
  - Foetus clearly hears speech VOWELS and musical RHYTHMS
  - Can discriminate between and habituate to sounds
  - Can be aroused by external noise

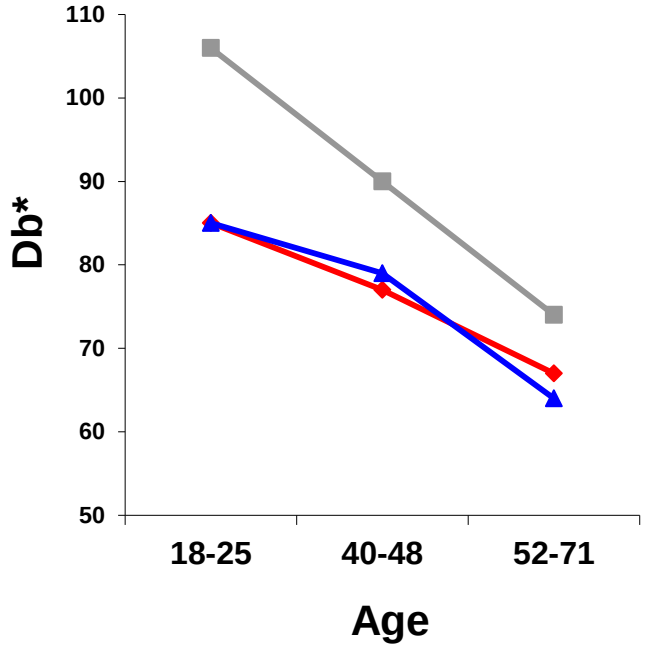
Source: Gerhardt & Abrams (2000). Fetal Exposures to Sound and Vibroacoustic Stimulation. J of Perinatology 20: 20-29

AATs and Age

Women



Men



Source: Zepelin et al (1984)

*1000 Hz tone

Sleep & Sound: Phylogeny

- The pleistocene plains were pretty dangerous at night…

- Being **awoken** by noise – and being **vigilant** before sleep is ADAPTIVE – these propensities evolved

Sound and Sleep

In addition to sound pressure, sleep is influenced by…

- Pitch and pattern: 520Hz square wave = the lowest AAT for fire alarms (Bruck et al, 2009)
- The personal *relevance* of the sound

Sound and Sleep

Noise can have 2 distinct impacts on sleep:

- It can interrupt sleep (as shown by AATs)
- It can delay the *onset* of sleep

- Signal *relevance* applies to both outcomes – but differently

Sound Relevance & Awakenings

- Arousals more likely after hearing own name versus control names (Oswald et al, 1960)
- Infant crying is more likely to wake women [but not men] than are other – louder – sounds.
- We process auditory information during sleep

Sleep Onset (falling asleep)

Sleep onset is most probable when:

- we are appropriately sleepy;
- we go to bed at the appropriate an time;
- the sleep environment is familiar and associated with restfulness; and
- we are appropriately calm or de-aroused.

Sleep and Arousal

- Thinking creates cognitive arousal
- Being ‘alert’ or ‘cognitively aroused’ delays sleep onset
- Delayed sleep onset also allows individuals the opportunity to think
- This process is amplified where thoughts are emotionally negative

Sound Relevance & Sleep Onset

- Where sounds or noise are associated with undesired situations – auditory awareness of that situation produces cognitive arousal
- This “cued” cognitive arousal can lead to chronic sleep disturbance in a robust minority of susceptible people

The Wind-Turbine Paradox

- Bakker et al (2012) used SEMs to examine the combined influence of WTN and annoyance on sleep disturbance
- Sleep disturbance significantly mediated by annoyance with the presence of wind turbines
- Sound cues annoyance – annoyance triggers cognitive arousal

Conclusions

- From the earliest development of human hearing, sleep is accompanied by noise
- In adulthood noise can impact sleep as acoustic energy or cognitive arousal
- Subjective estimates of sleep are typically inaccurate, but nearly always useful