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Sleep Measurements in Animals




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Sleep Measurements in Animals

EEG-based Sleep Recording

- **Laboratory rat and mouse**
- Other species

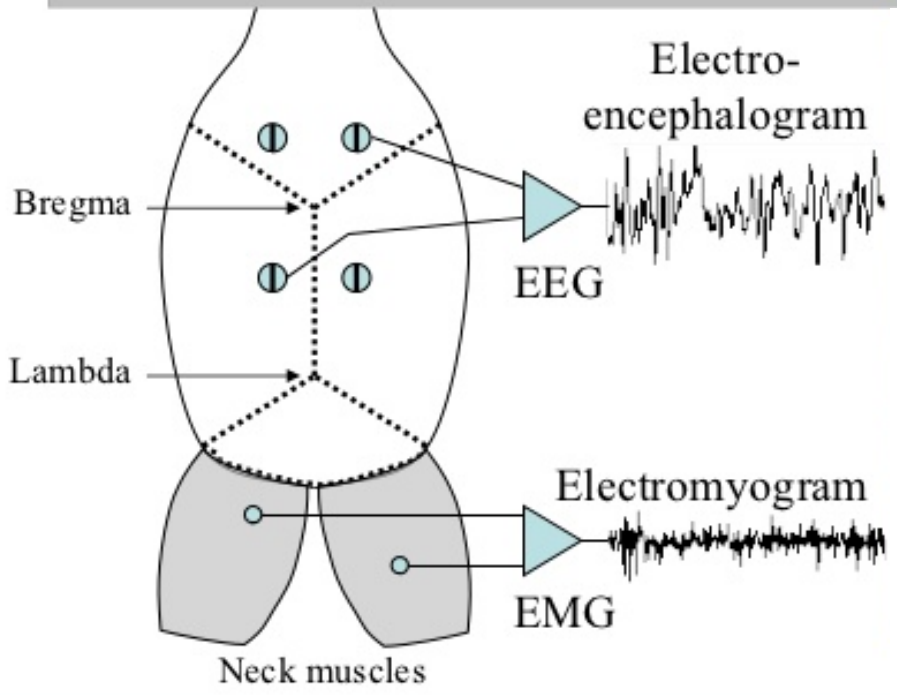
Alternative Approaches

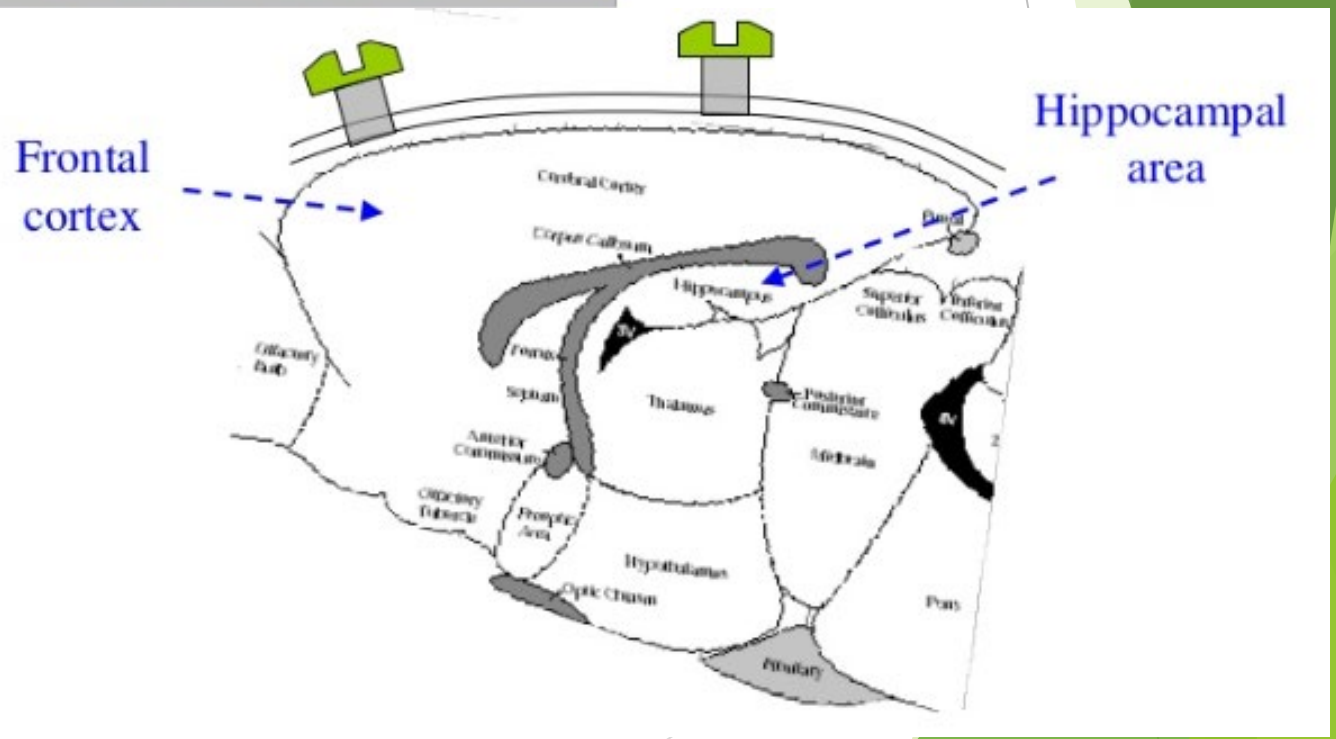
- Actigraphy
- Piezo Sleep Behavioral Tracking
- Electric Field Sensing
- Video-based analyses

EEG-based Sleep Recording: Rat/Mouse

- Electroencephalography (EEG) + Electromyography (EMG)

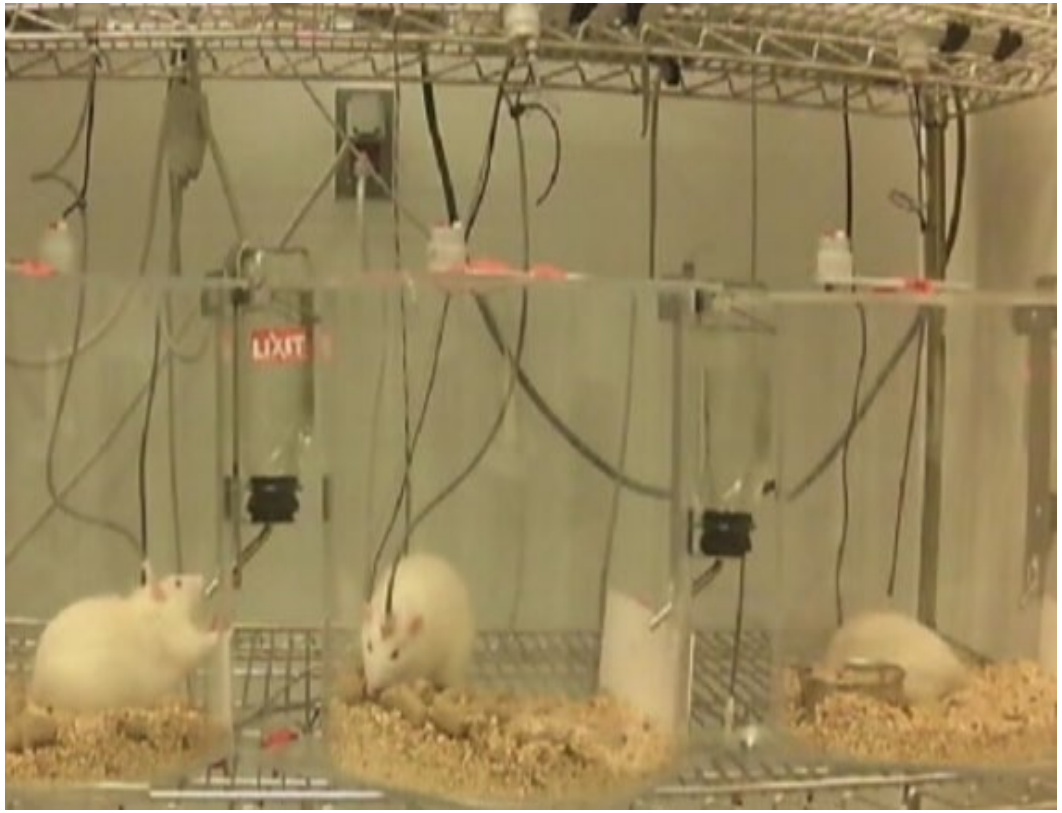
Cortical EEG and neck muscle EMG signals can be visually scored to yield three sleep/wake state: wake, slow-wave sleep (SWS), and rapid-eye movement sleep (REMS).





EEG-based Sleep Recording: Rat/Mouse

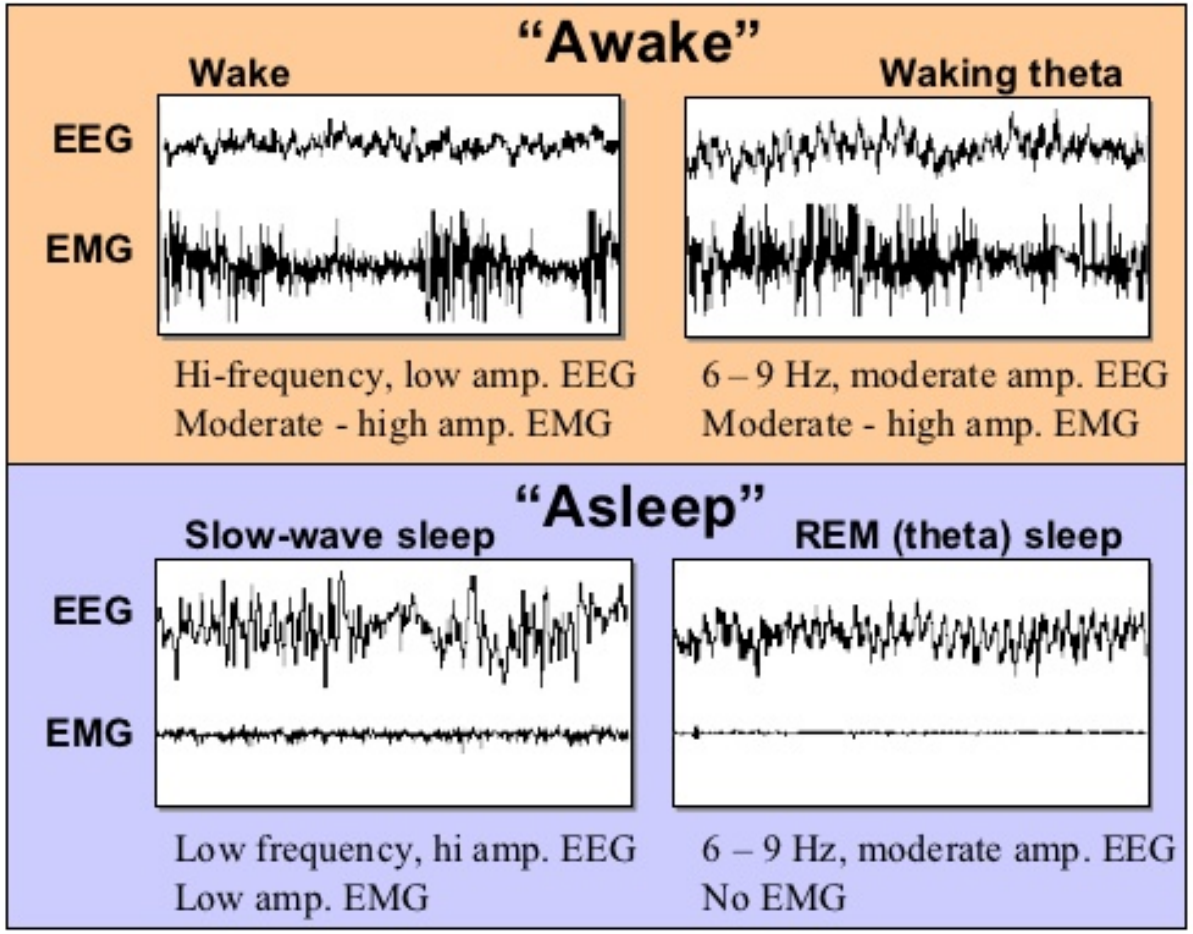
Tethered

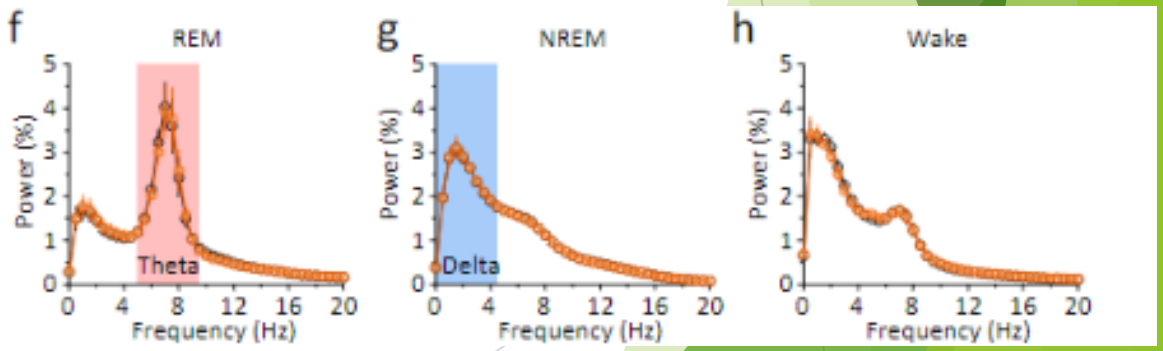


Wireless

EEG-based Sleep Recording: Sleep Scoring

- Waveform-based: Amplitude and Frequency



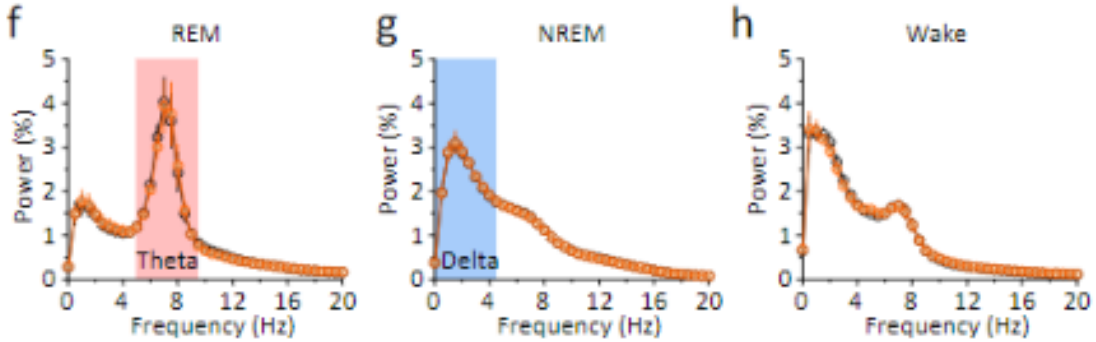


EEG-based Sleep Recording: Data Analysis

- Sleep Time Analysis
  e.g. 24-hr/12-hr total wake/NREM/REM time, sleep latency.

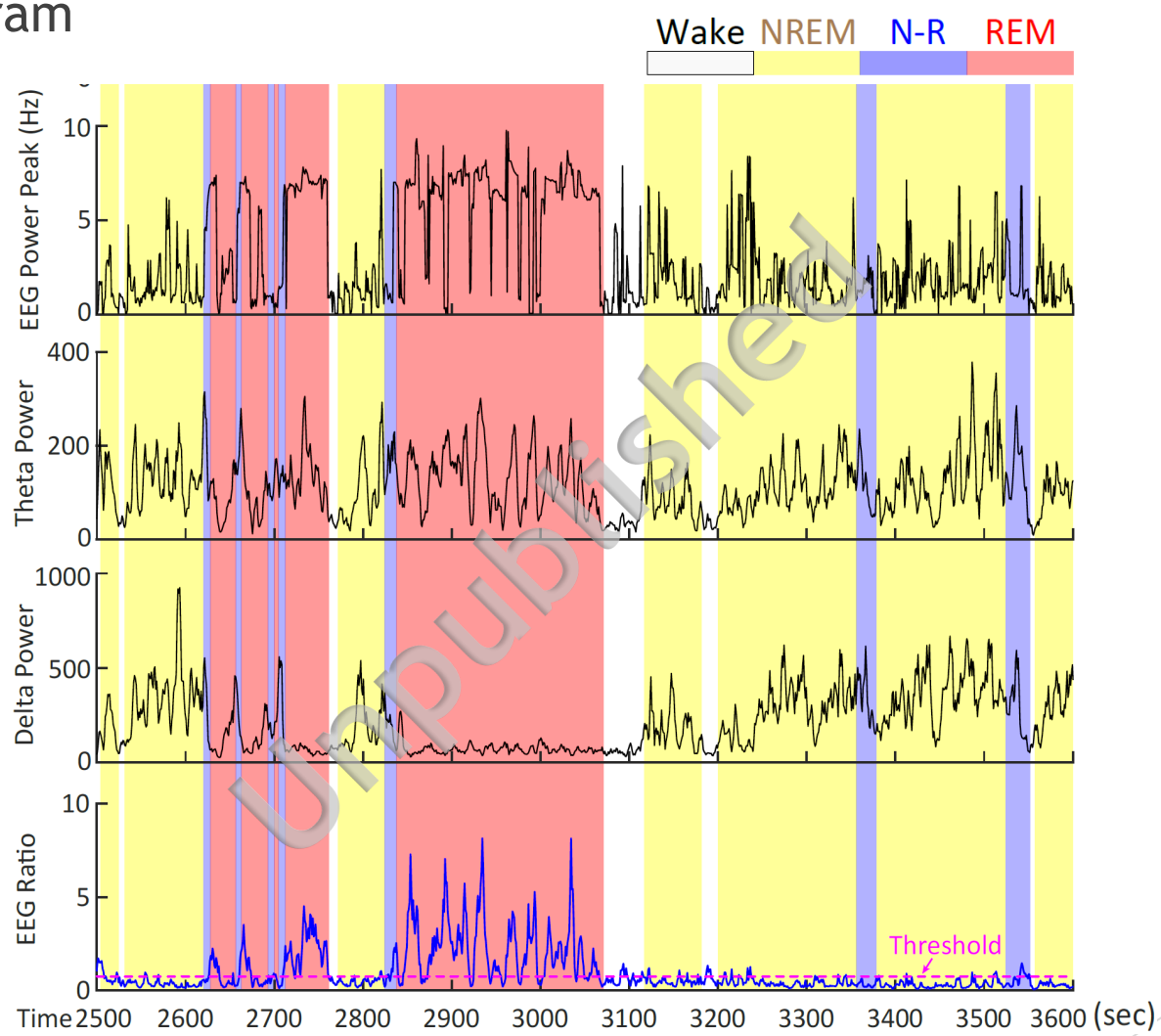
- Bout / Transition Analysis
  e.g. wake/NREM/REM bout number/duration, transition #.

- Power Spectrum Analysis
  e.g. Power distribution (FFT), Slow wave amplitude (SWA), etc.



EEG-based Sleep Recording: Data Analysis

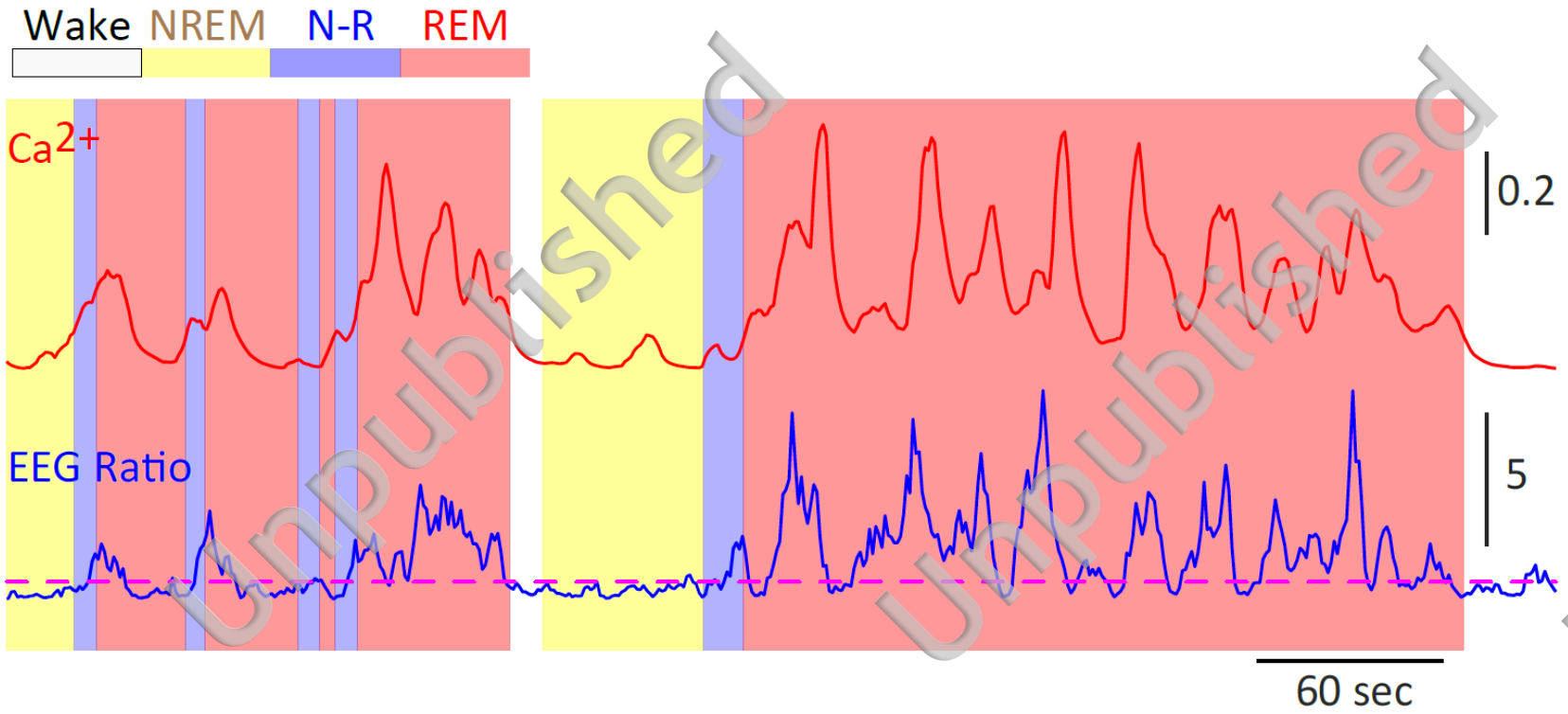
- EEG spectrogram

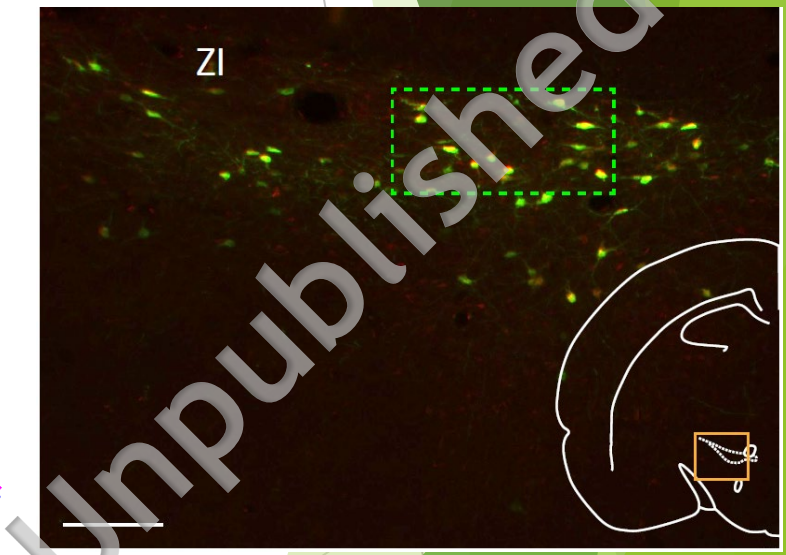


(Wang et al., unpublished)

EEG-based Sleep Recording: Data Analysis

- EEG spectrogram





(Wang et al., unpublished)

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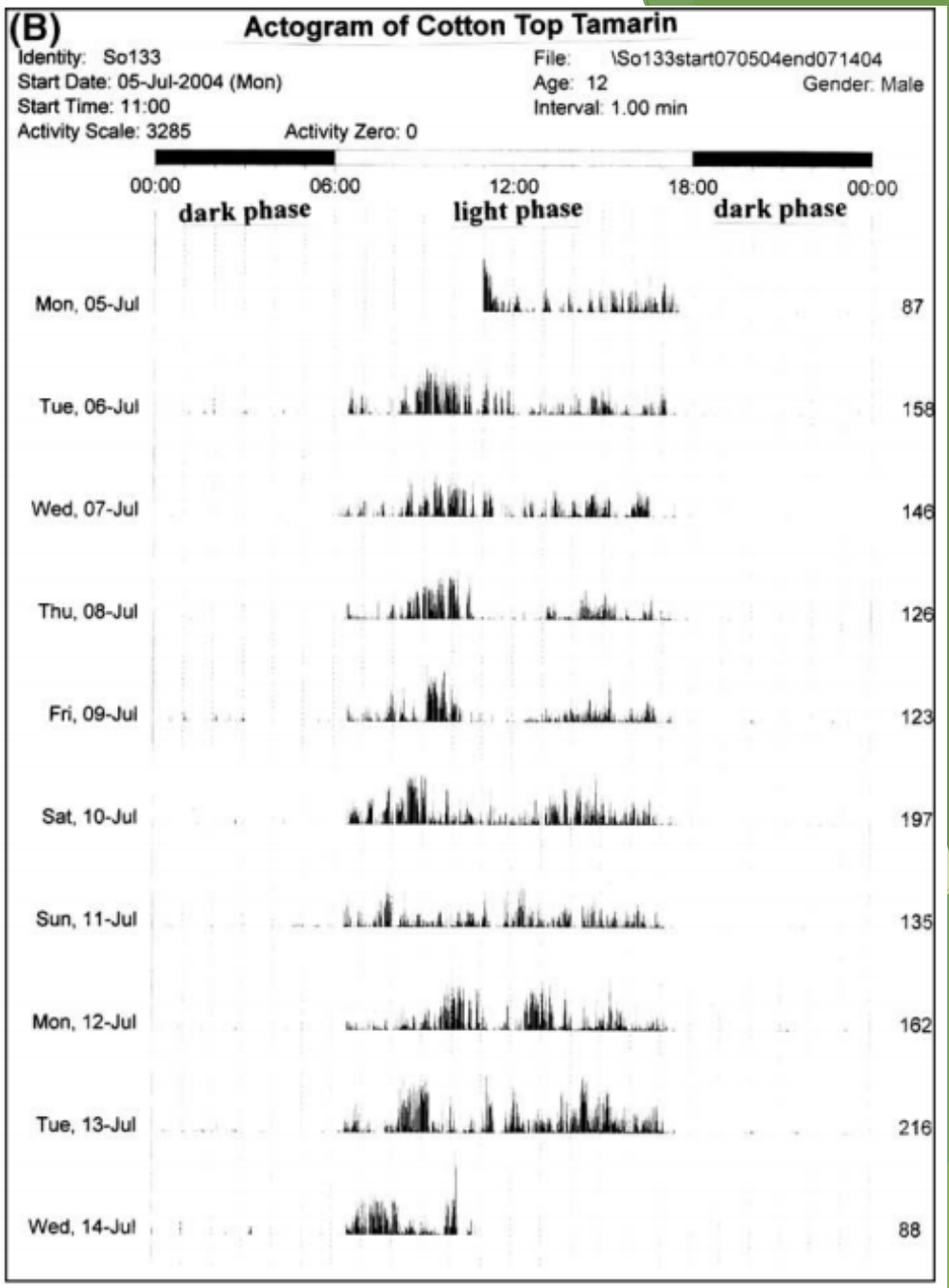
Alternative Approaches

- Actigraphy
- Piezo Sleep Behavioral Tracking
- Electric Field Sensors
- Video-based posture analysis

Alternative: Actigraphy

- Nonhuman primates
- Similar to human actigraphy
- Long-term; non-invasive
- Wake (active) vs. Sleep (inactive)
- Does not differentiate NREM vs REM sleep



Sachi Sri Kantha, et al., 2006, Comp Biochem & Physi

Alternative: PiezoSleep Behavioral Tracking

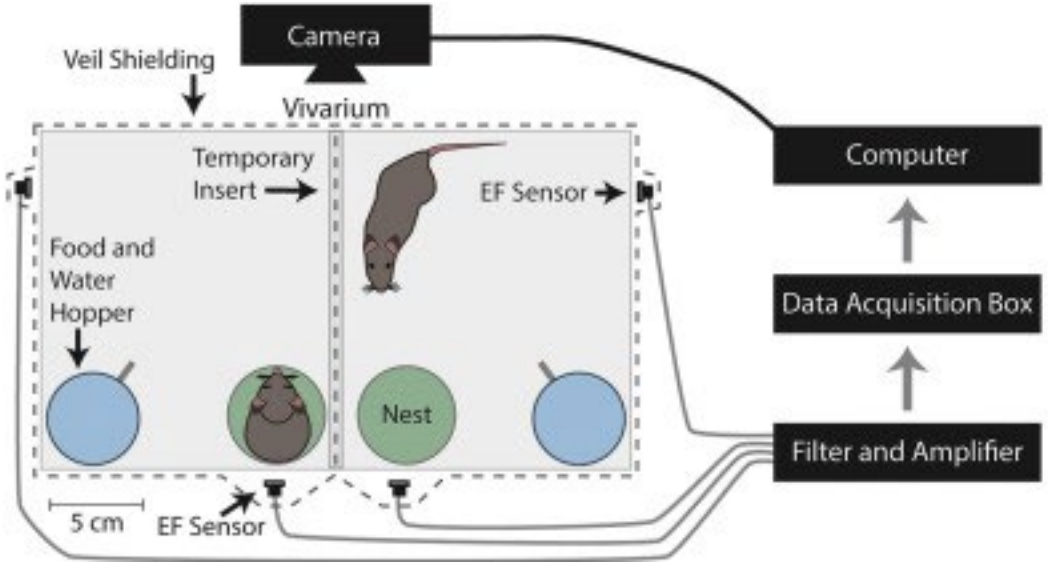
- Piezoelectric sensor pad (piezoelectric PVDF polymer).
- Pressure variations associated with respiratory patterns and movement.
- Wake (active) vs. Sleep (inactive).
- NREM (regular breathing) vs. REM (irregular breathing).
- Long-term; non-invasive; high throughput.

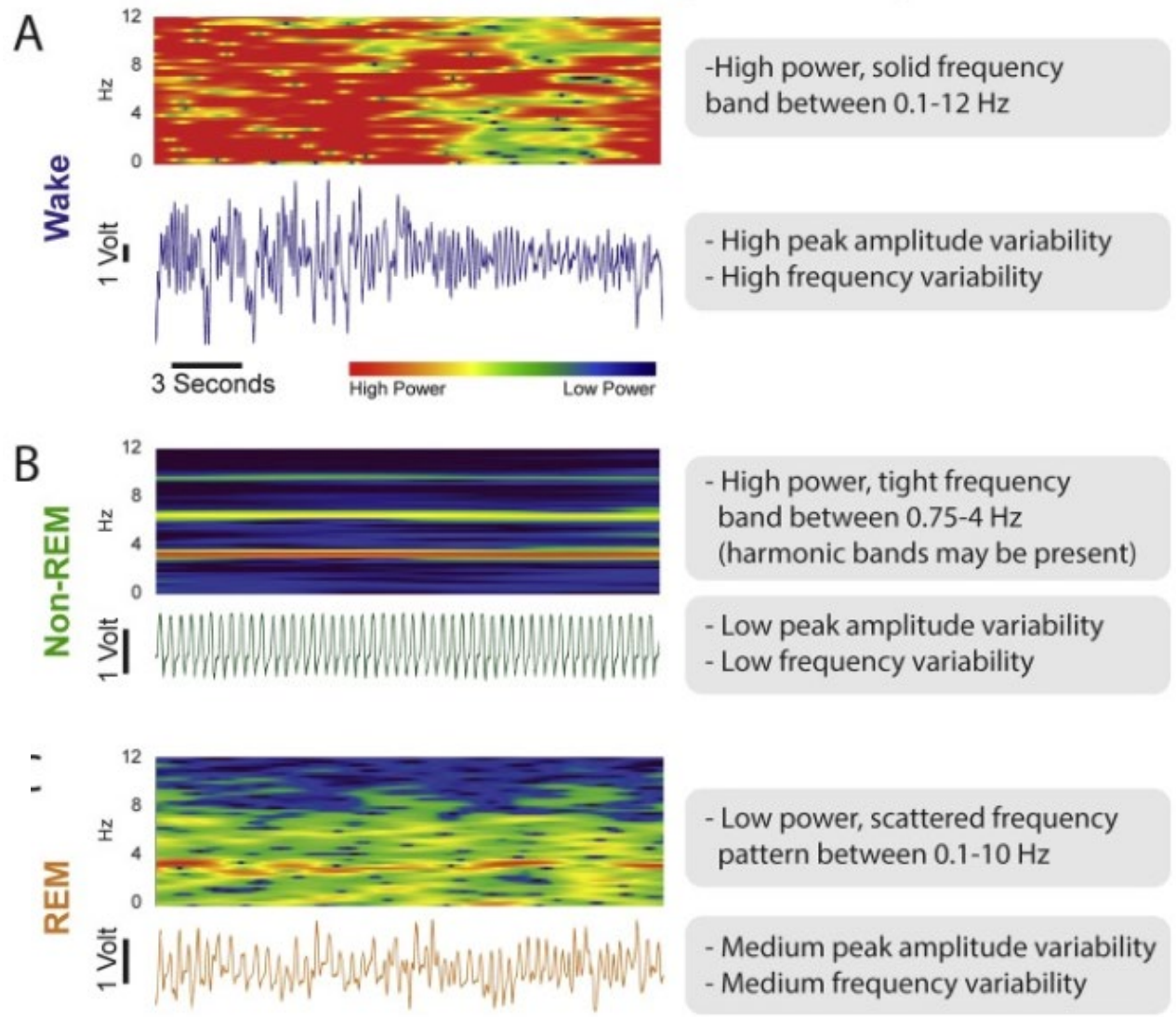
www.sigsoln.com

GM Mang et al., 2014, Sleep; F Yaghouby et al., 2016, J Neuro Methods.

Alternative: Electric Field Sensors

- EF sensors attached to the exterior of chambers/home cages.
- Detect fluctuations in the local electric field caused by motion (respiration and other movements).
- Wake vs. NREM vs. REM.
- Long-term; non-invasive; high throughput.

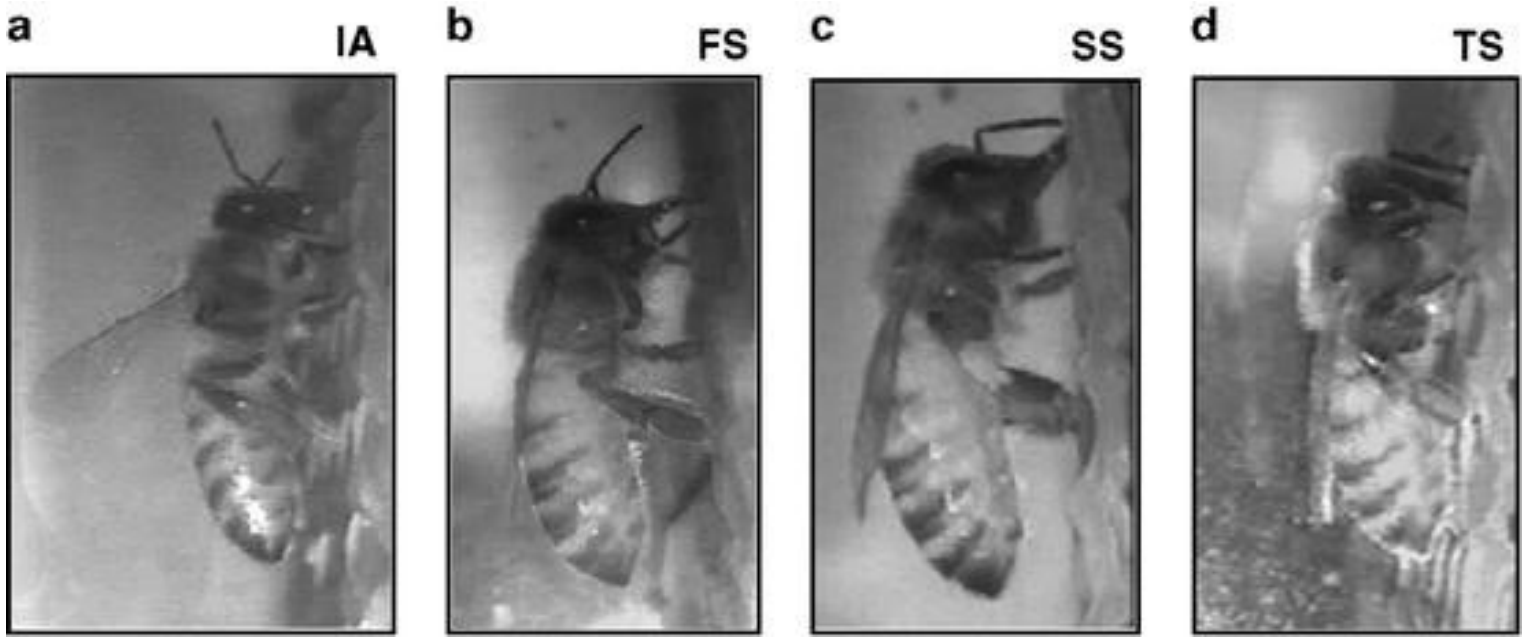




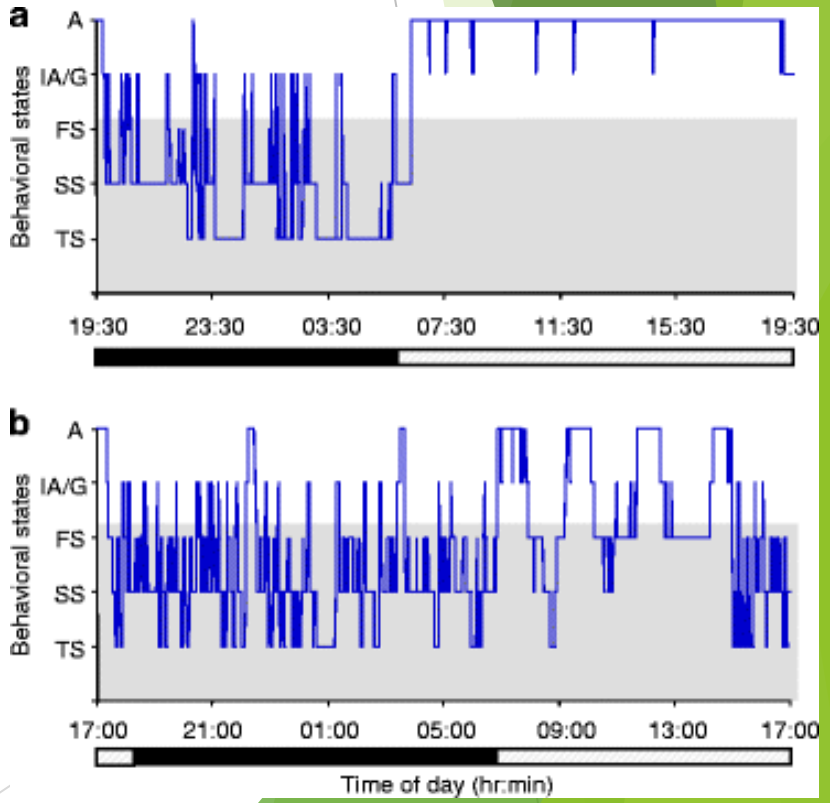
H Kloefkorn, et al., 2020, J Neuro Methods.

Alternative: Video-based analysis

- Sleep Behaviors: sleep postures; immobility; reduced muscle tone; lowered body temperature; raised reaction threshold.
- Video Observation: postures; discontinuous ventilation pumping motions in the abdomen; antennae immobility.

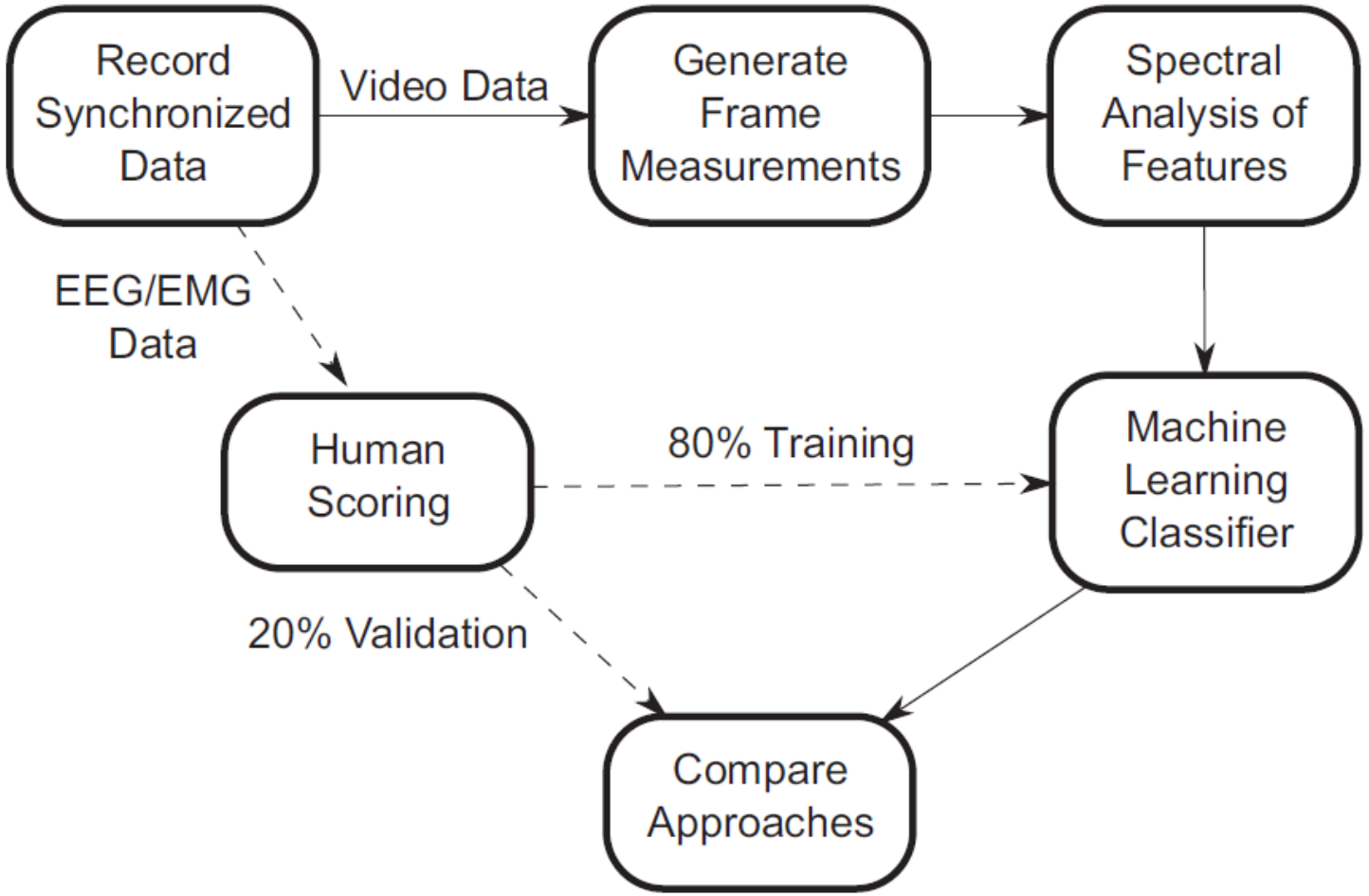


Immobile-active | First sleep | Second sleep | Third sleep



W Kaiser, 1988, J Comp Physiol; BA Klein, 2008, J Exp Bio; A Eban-Rothschild, 2011, Honeybee Neurobio & Behav

Alternative: Video-based analysis



Geuther et al., *Sleep*, 2022

Alternative: Video-based analysis

Table 5. Performance comparison across published approaches

Approach	Wake			NREM			REM			Overall
	Accuracy	Precision	Recall	Accuracy cc.	Precision	Recall	Accuracy	Precision	Recall	Accuracy
Video (mice) [34]										0.767
Doppler (rats) [31]	0.916	0.898	0.834	0.851	0.852	0.917	0.697	0.718	0.615	0.844
Piezo (mice) [26]	0.91	0.841	0.9	0.831	0.717	0.81	0.834	**0.815**	0.66	0.787
Electric field* (mice) [33]			0.938		0.943	**0.943**			0.834	**0.94**
Ours (mice)	**0.961**	**0.984**	**0.961**	**0.914**	**0.951**	0.914	**0.898**	0.535	**0.897**	0.92

Bold indicates best performing approach for each metric.
*Electric field approach uses human annotation, not a machine learning algorithm.

Geuther et al., *Sleep*, 2022

Resources

- EEG Sleep Wake Evaluation
- https://www.slideshare.net/jagruner/eeg-sleep-wake-evaluation-8665088

- Mouse Epidural EEG Electrode Surgery
- https://www.youtube.com/watch?v=9ErECVu4jjQ

- Rat Epidural EEG Electrode Surgery
- https://www.youtube.com/watch?v=l8QhmnirgyU

- In vivo EEG recording in rats
- https://www.slideshare.net/InsideScientific/measuring-eeg-in-vivo-for-preclinical-evaluation-of-sleep-and-alzheimers-disease