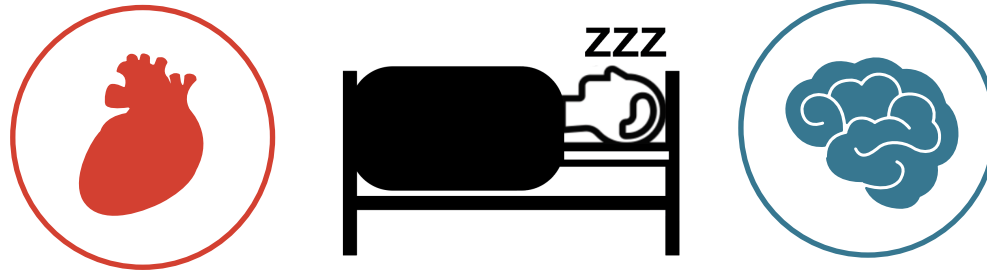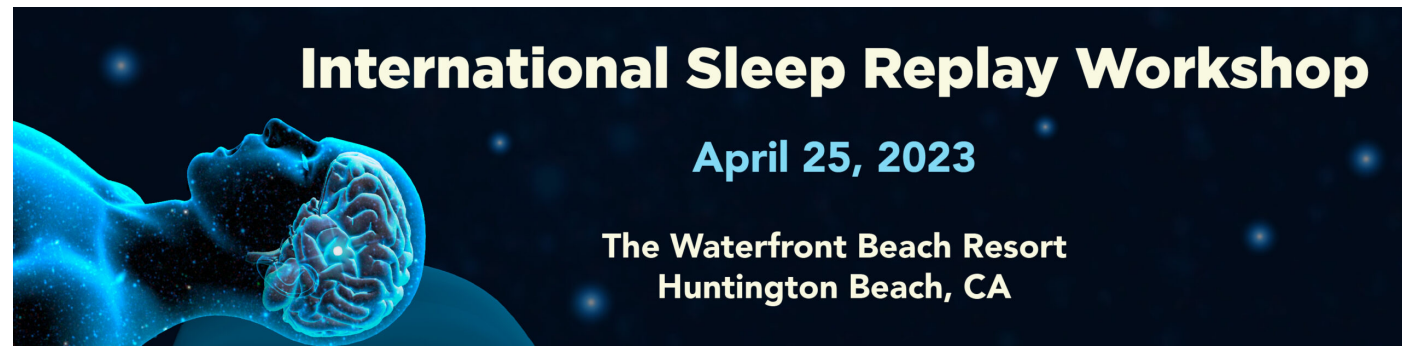# Integrating measurements of the autonomic nervous system and heart-brain interactions with sleep and memory research

Pin-Chun Chen, University of Pennsylvania
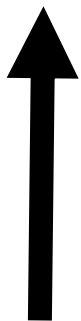
International Sleep Replay Workshop

April 25, 2023

The Waterfront Beach Resort
Huntington Beach, CA

CNS and ANS are Linked

Central Autonomic Network (CAN):
mPFC, Cingulate, Insula, Amygdala

10%

90%

Vagus Nerve
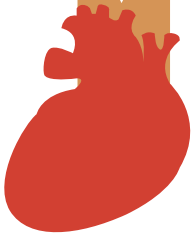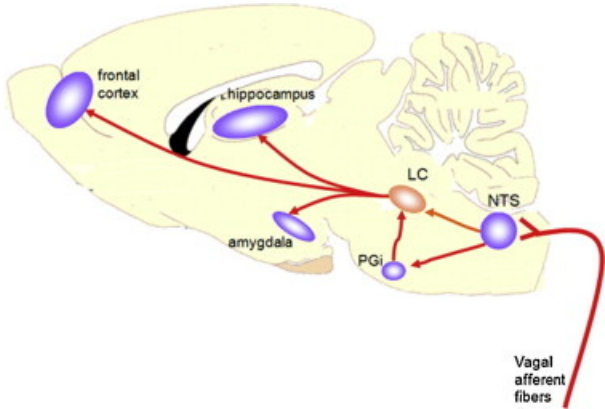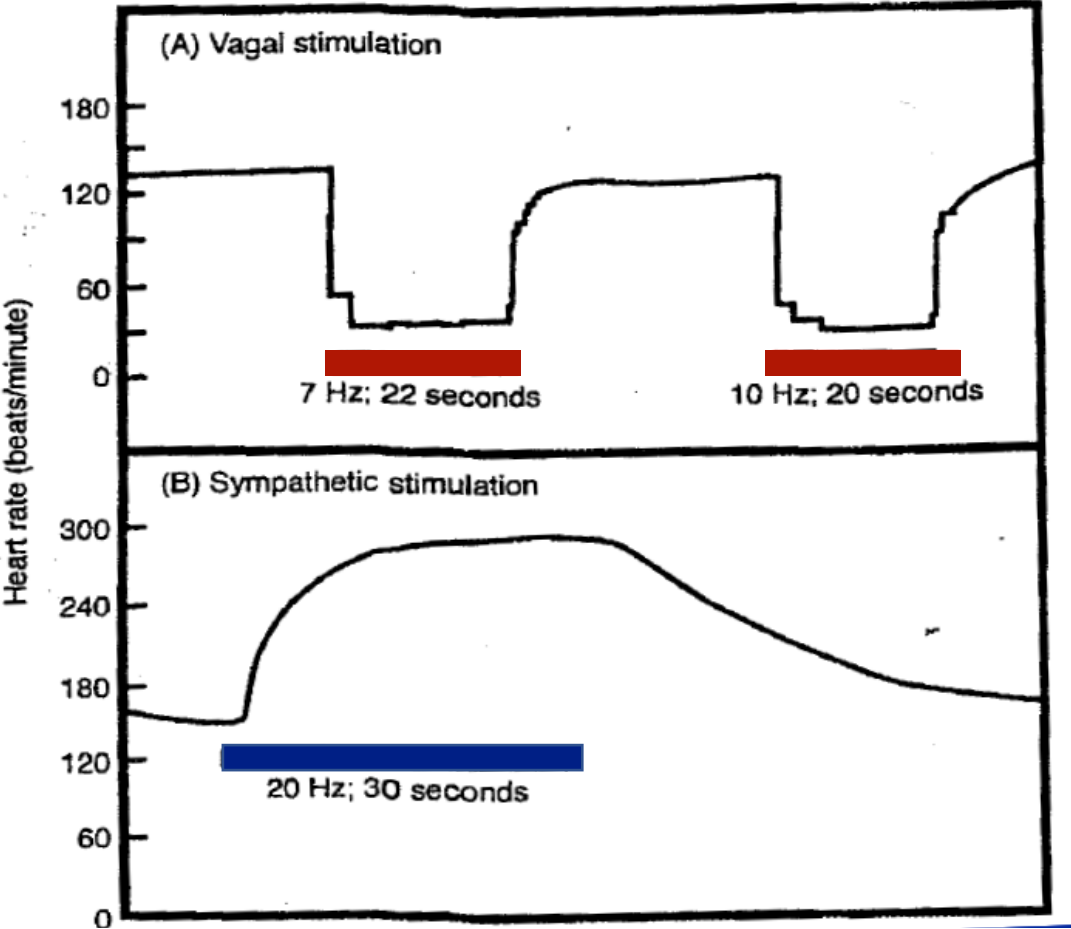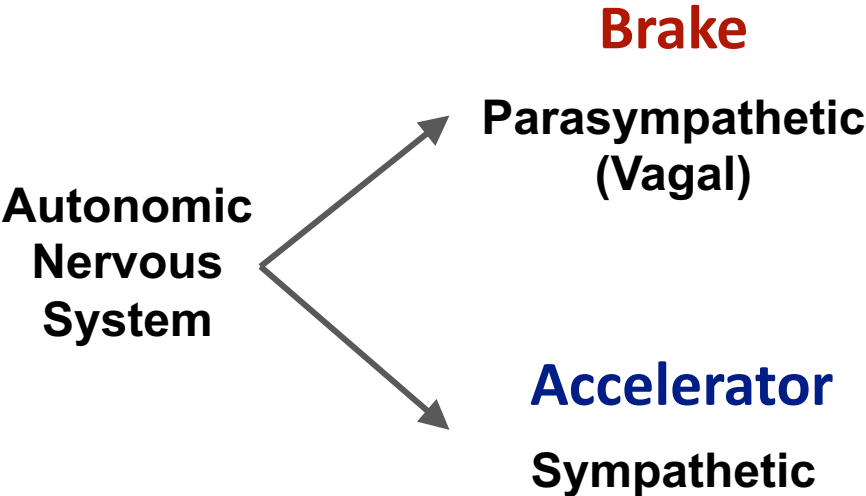
This feed-back and feed-forward
loop generate complex variability
of heart rate (HRV).

Thayer and Lane, 2000; 2009

Williams & McGaugh, 1993; McIntyre, McGaugh, Williams, 2012

Vagal Modulation of Heart Rate

Brake

Parasympathetic (Vagal)

Autonomic Nervous System

Accelerator

Sympathetic

Warner & Cox 1962
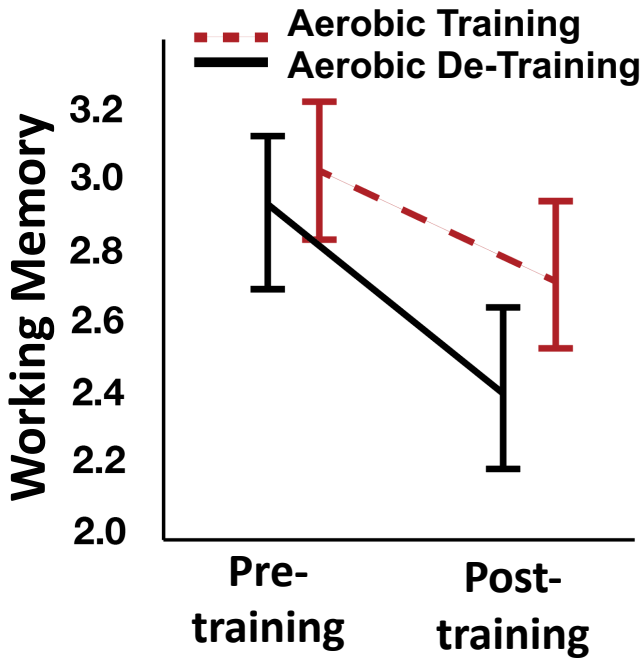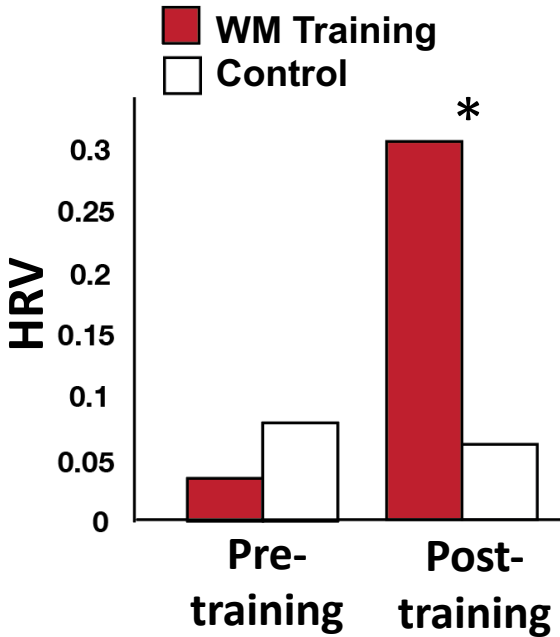
Vagally-Mediated HRV & Working Memory (WM)
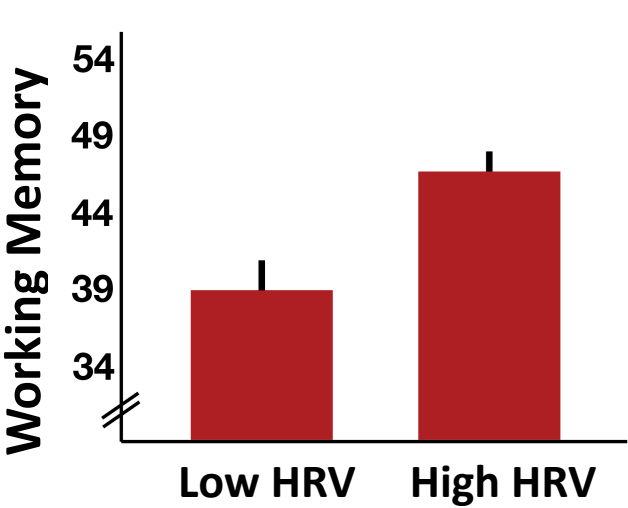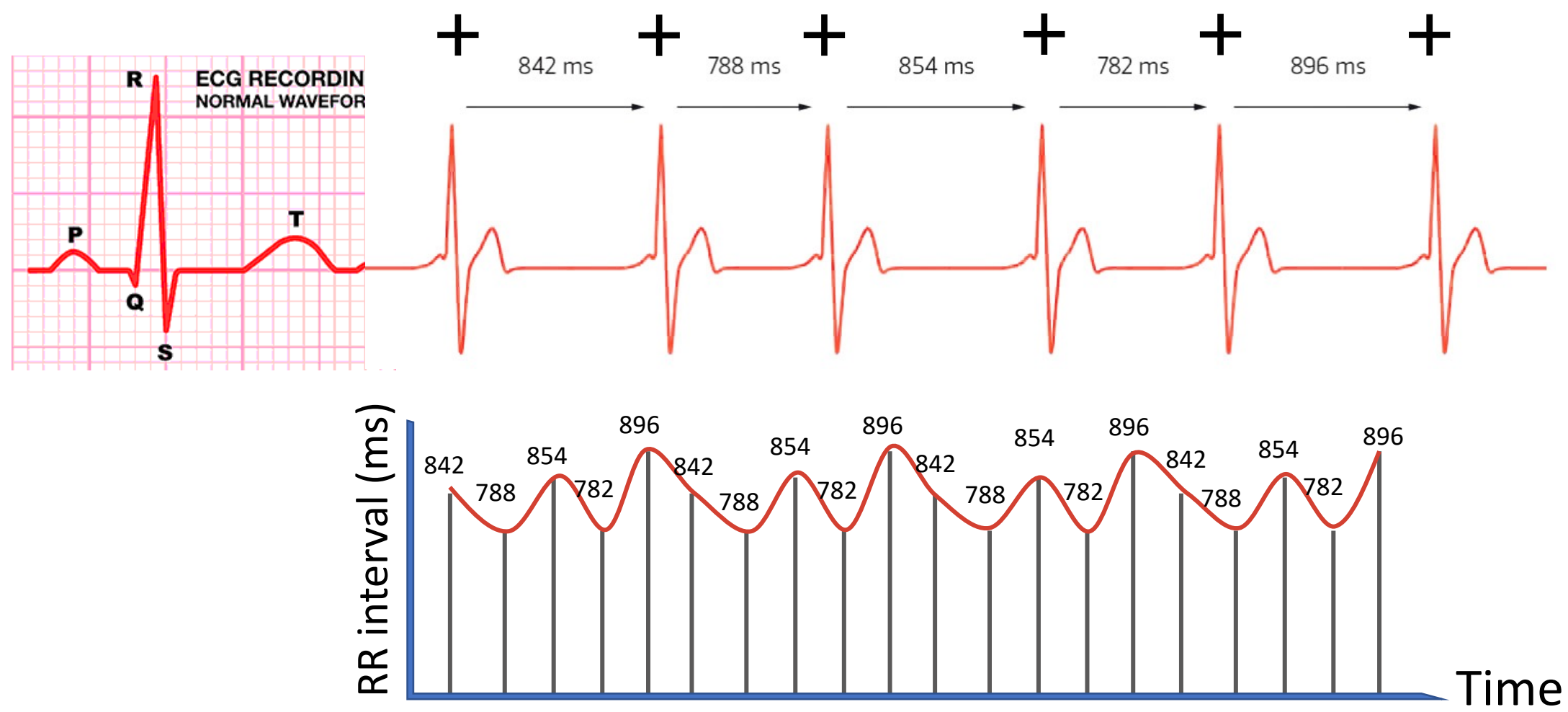

*Adapted from
Hansen et al., 2003*

*Adapted from
Hansen et al., 2004*

*Adapted from
Xiu et al., 2016*

# From R-R Time Series to Heart Rate Variability (HRV)

Task Force of the European Society of Cardiology and
North American Society of Pacing and Electrophysiology (Malik, 1996)

R-R Intervals / Inter-Beat Interval (IBI)

- ECG Recording
  - 125Hz minimum sampling rate
  - 500Hz recommended
- Detrend
  - Matlab: polyval
  - Kubios: Smoothness priors method: remove only VLF frequency components from the RR time series (Tarvainen et al. 2002)
- R peaks detection
  - Kubios software
  - Matlab: findpeaks
- Artifacts Detection
  - Normal range of RR: 0.5 to 2 seconds
  - Local average
    - RR intervals that are larger/smaller than 0.25 seconds compared to the local average
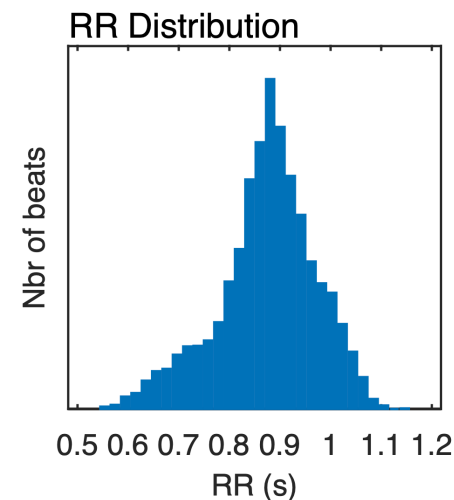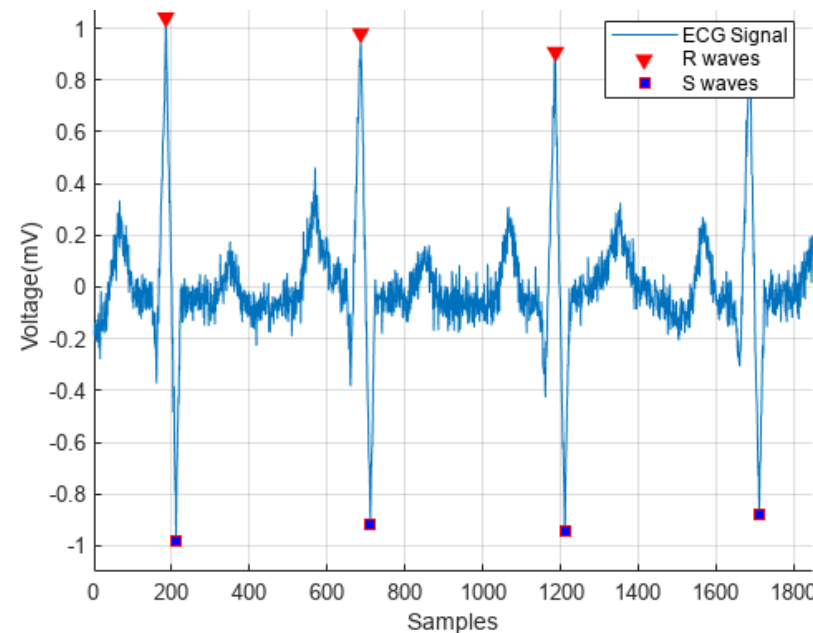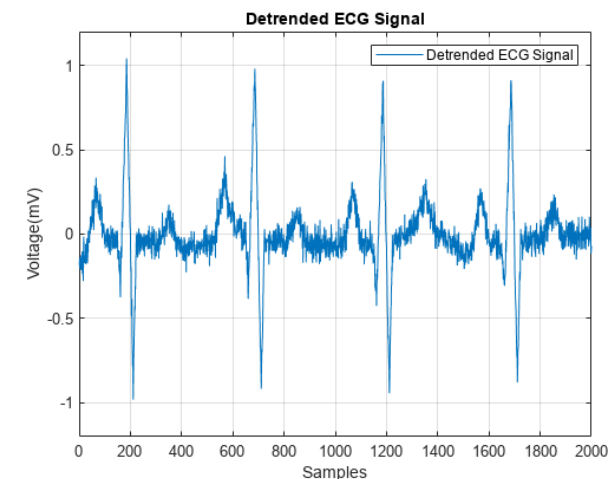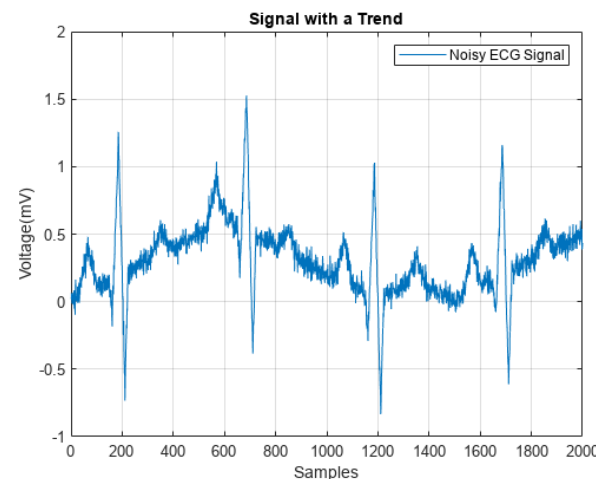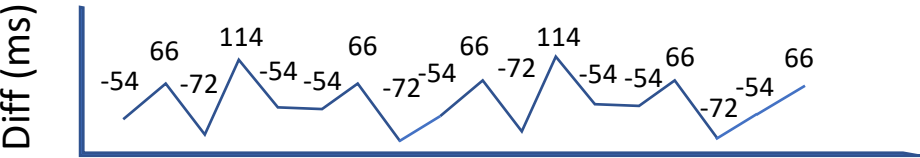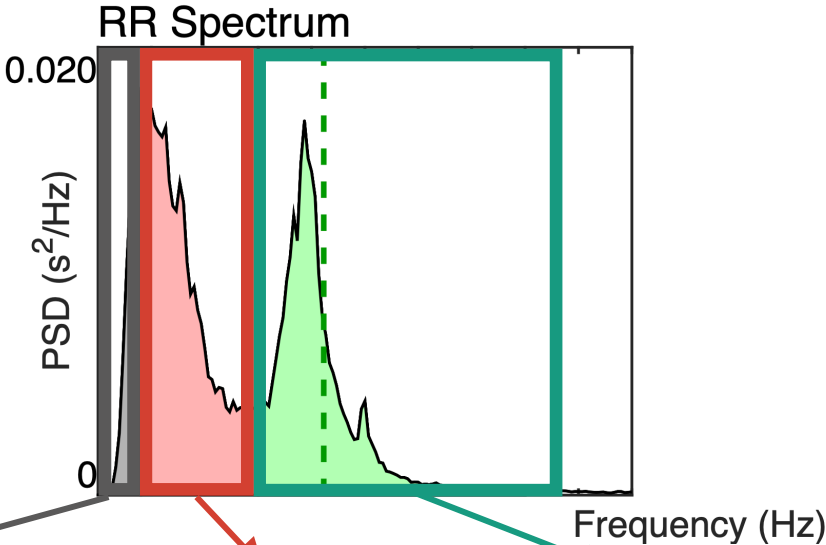
Heart Rate Variability (HRV)

Time-domain
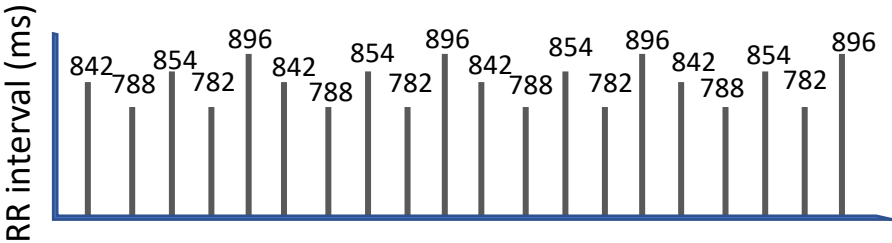
Frequency-domain

- SDNN: std of all RR intervals

- RMSSD: root mean square of successive differences

  Correlated with HF (r = 0.95)

- pNN50: % of successive normal RR intervals differences more than 50ms

VLF
0-0.04Hz
Thermoregulation

LF
0.04-0.15Hz
Mix of vagal and sympathetic

HF
0.15-0.4Hz
Vagal tone

LF/HF Controversial

Normalized Unit:
HF% = HF/ (HF+LF)

Shaffer et al., 2014; Laborde et al., 2017

Common Challenges and Remedies

Problems

What variables to report?

Data not normally distributed

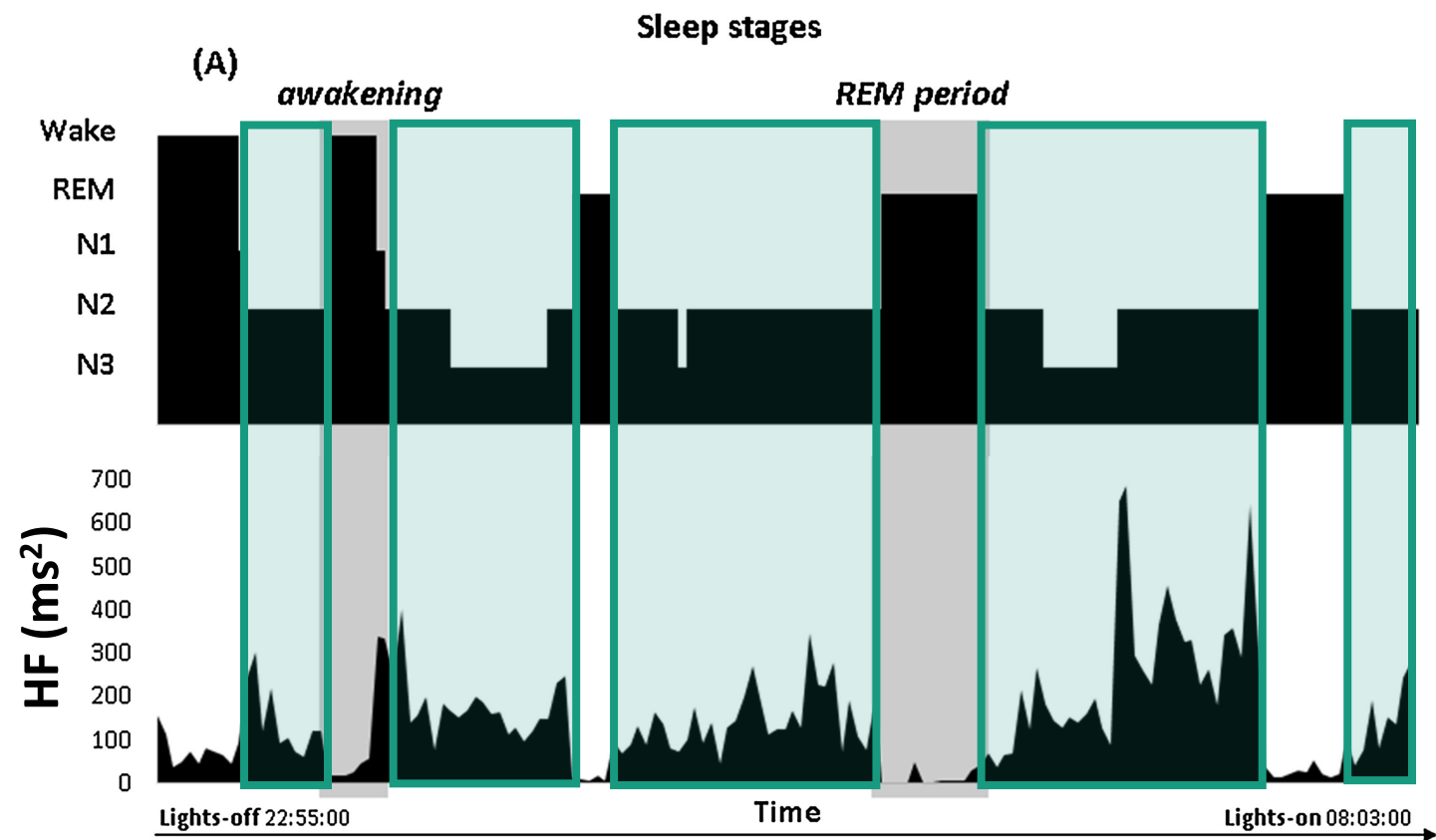Large individual differences

Affected by respiration?

Solutions

Choose one for main analyses
Report others in supplementary

Natural log

Within-subject design
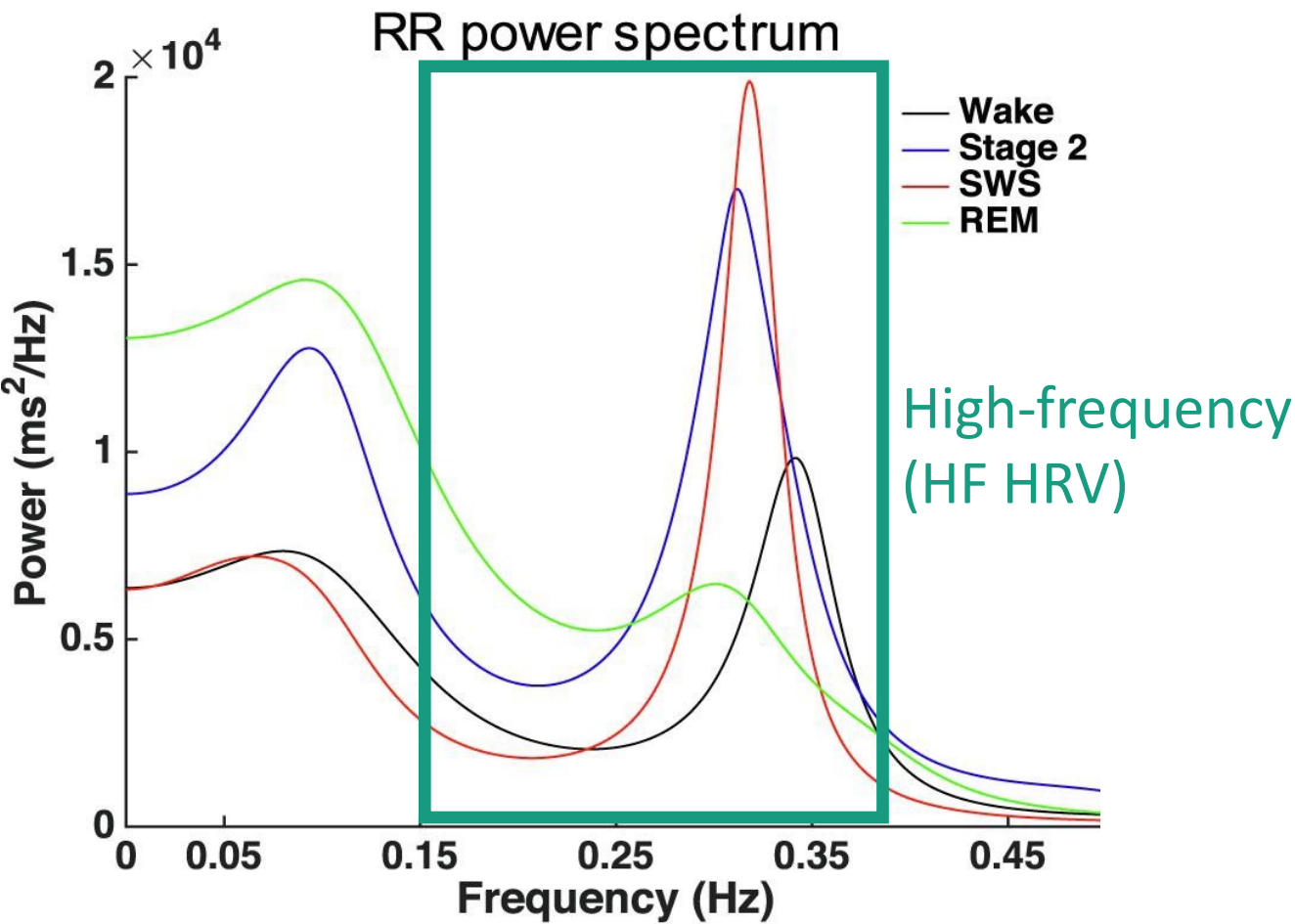
Time-domain unaffected
Autoregressive (AR) better than FFT

Kobayashi et al., 2012
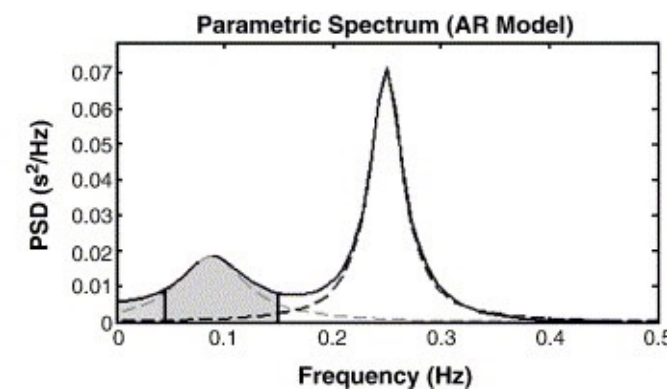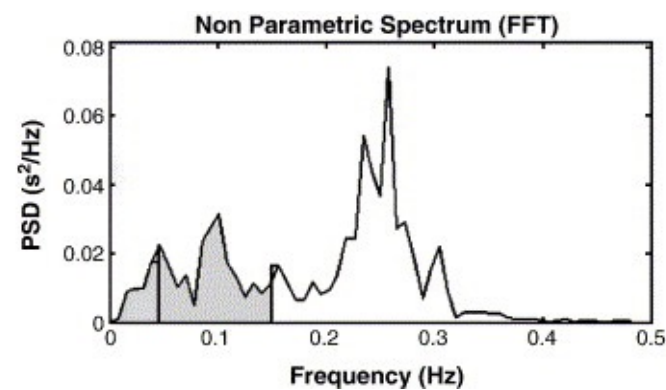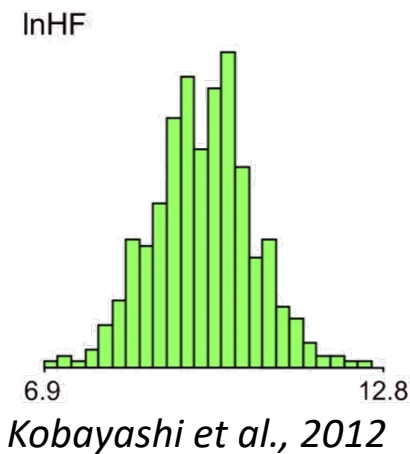
Fagard et al., 1998; Pichon et al., 2006; Larsen et al., 2010; Bertsch et al., 2012

Sleep is a cardiovascular holiday

Trinder et al., 2001, 2012

Nap is a mini-cardiovascular break

High-frequency (HF HRV)

Naji et al., 2019; Cellini et al., 2016; Whitehurst et al., 2018

HF during SWS Supports Working Memory Improvement

Chen et al. 2020 J. Cognitive Neuroscience
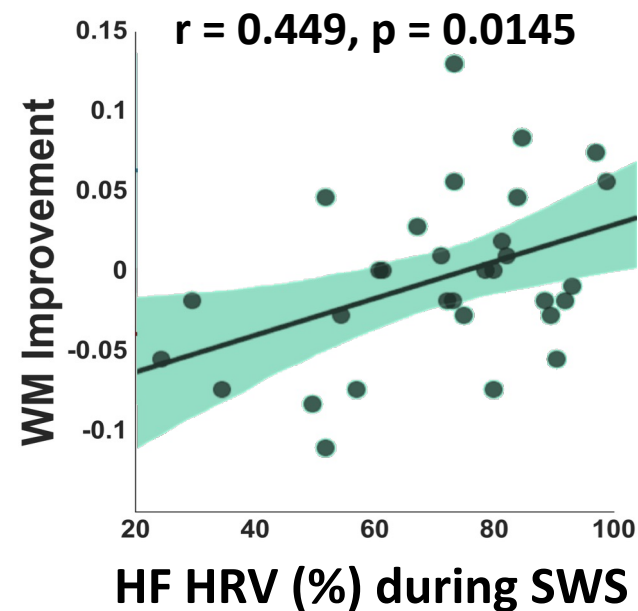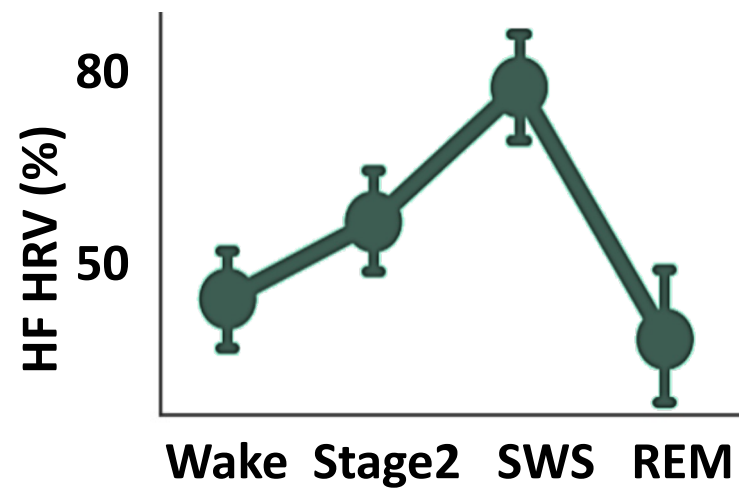
Zolpidem Decreases HF during SWS and Decreases Working Memory Improvement

Chen et al. 2021., PNAS