Workshop

How electrocardiogram can measure sleep quality

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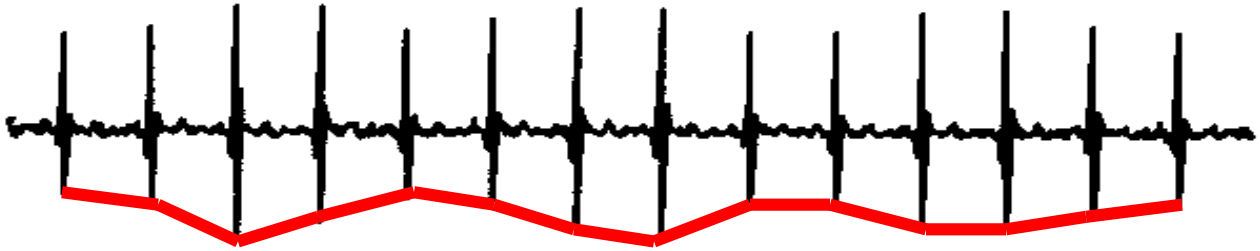
Primary Goal

Maximize the detectability of **para-sympathetic activity** using electrocardiogram (ECG)

Cardiopulmonary Coupling Analysis (CPC)

Heart Rate Signal

ECG



ECG-derived Respiratory Signals (EDR)

Respiration Signal

~ 10 seconds of data

Components of Cardiopulmonary Coupling Analysis

- Respiratory-related power in heart rate signal
- Respiratory power
- Correlation between heart rate and respiratory signal

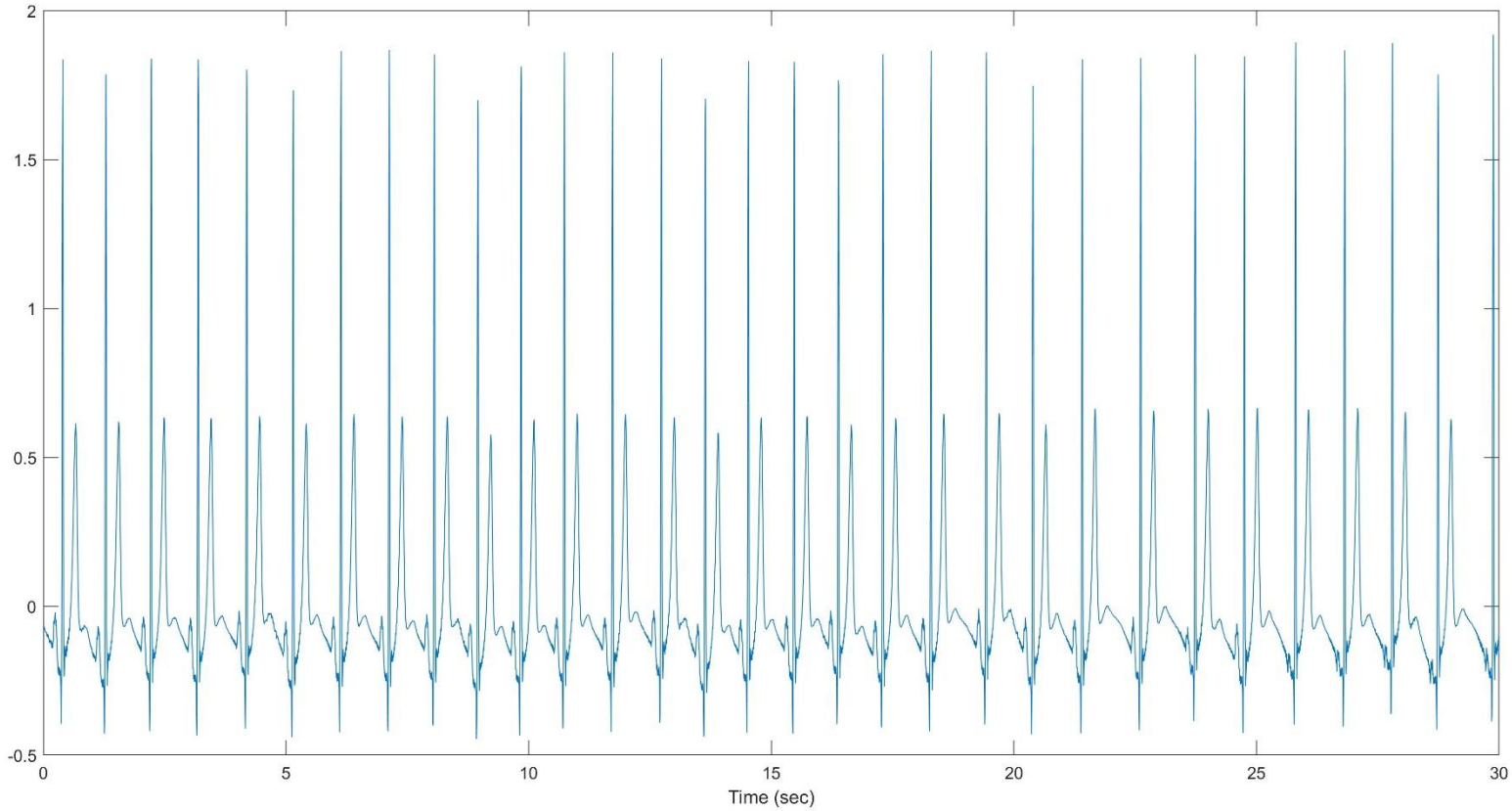
ECG Signal

Sampling rate = 200 Hz

Recorded in N3 sleep stage

- ecg = load('ECG_N3.txt');
- t=1/200:1/200:30;
- plot(t,ecg);
- xlabel('Time (sec)');

ECG Signal



Tasks

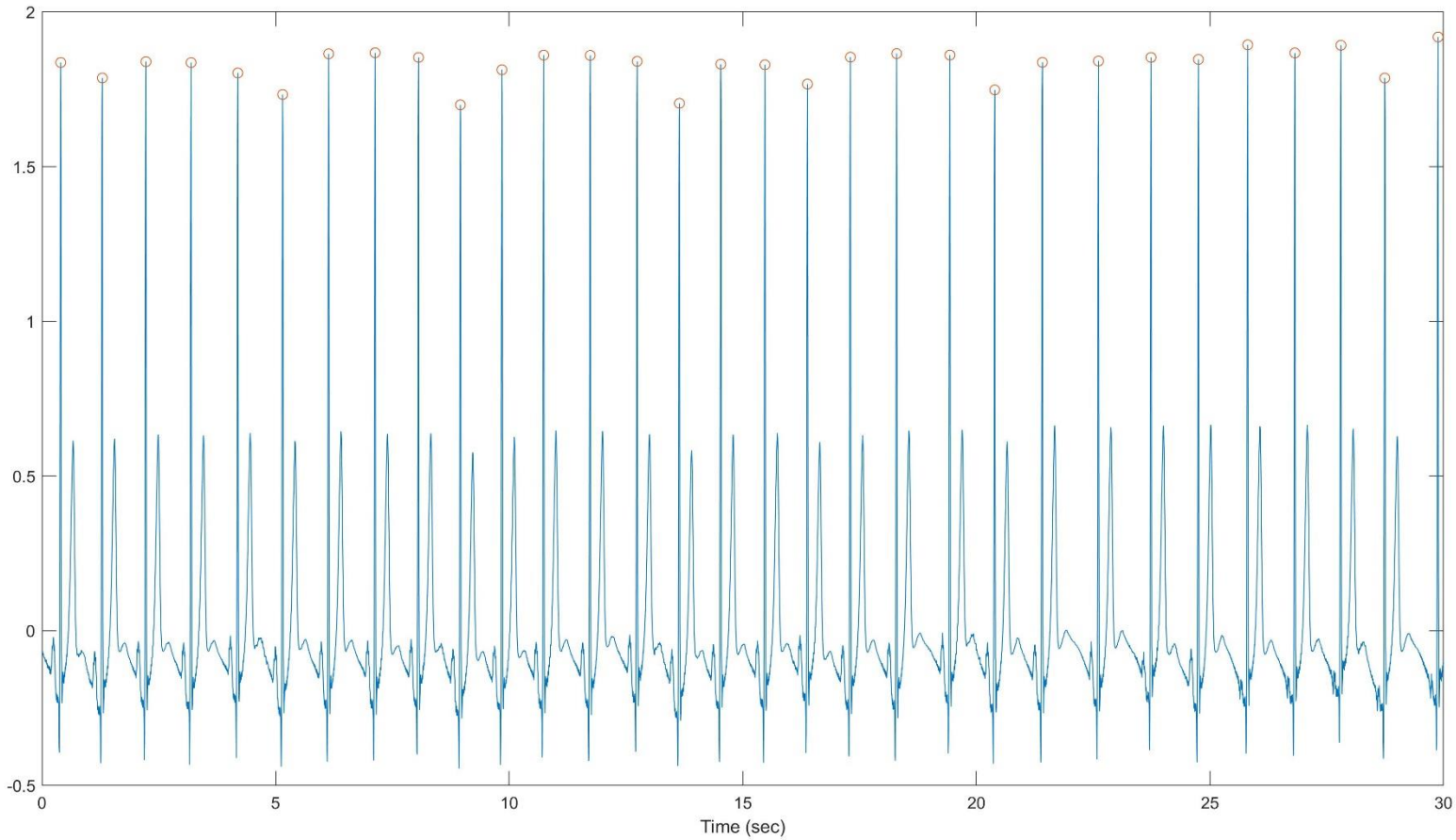
- Identify R-R intervals
  - Estimate respiratory-related power
- Extract ECG-derived respiration signal
  - Estimate respiratory power
- Estimate the correlation between R-R interval and respiration signal
  - Correlation vs. coherence

Identify R-R Intervals

- [pks,locs] = findpeaks(ecg,'MinPeakHeight',1);

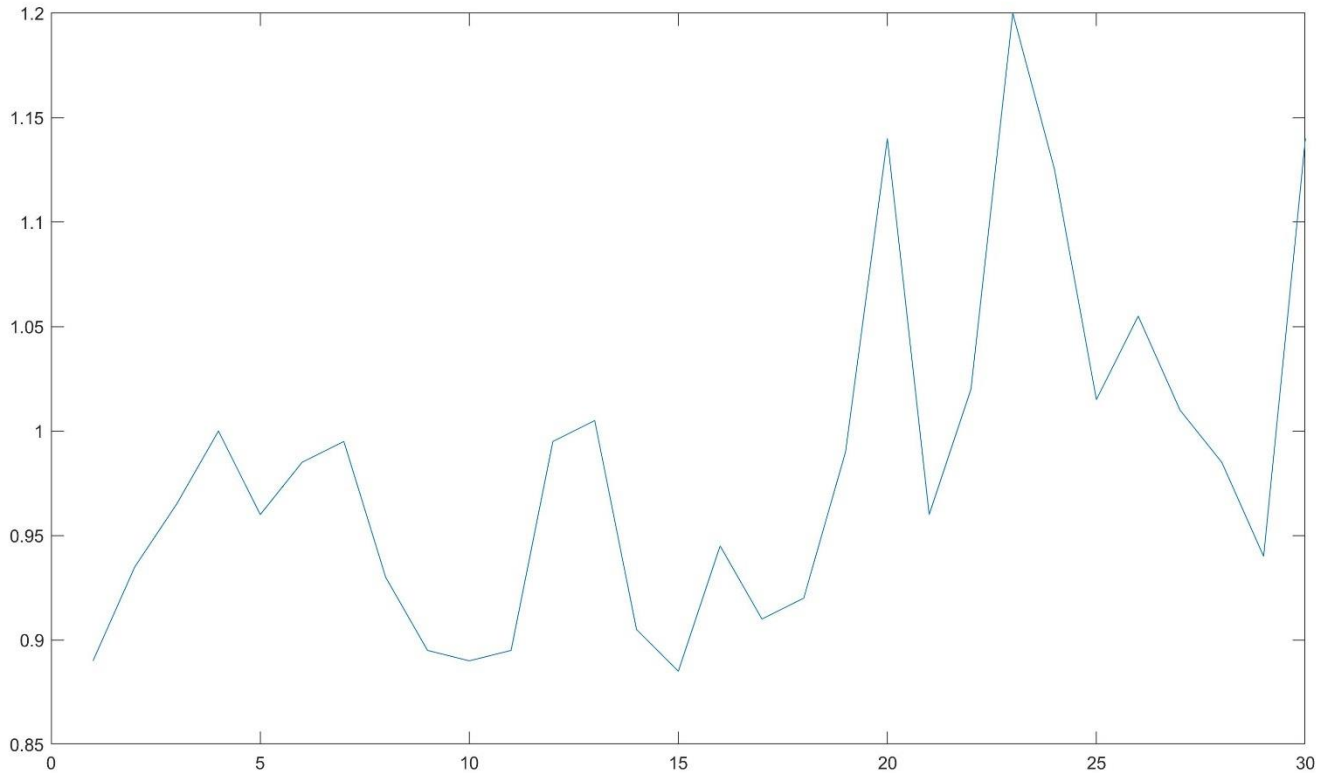
- hold on
- plot(locs/200,pks,'o');
- hold off

Identify R-Peaks



Calculate R-R Intervals

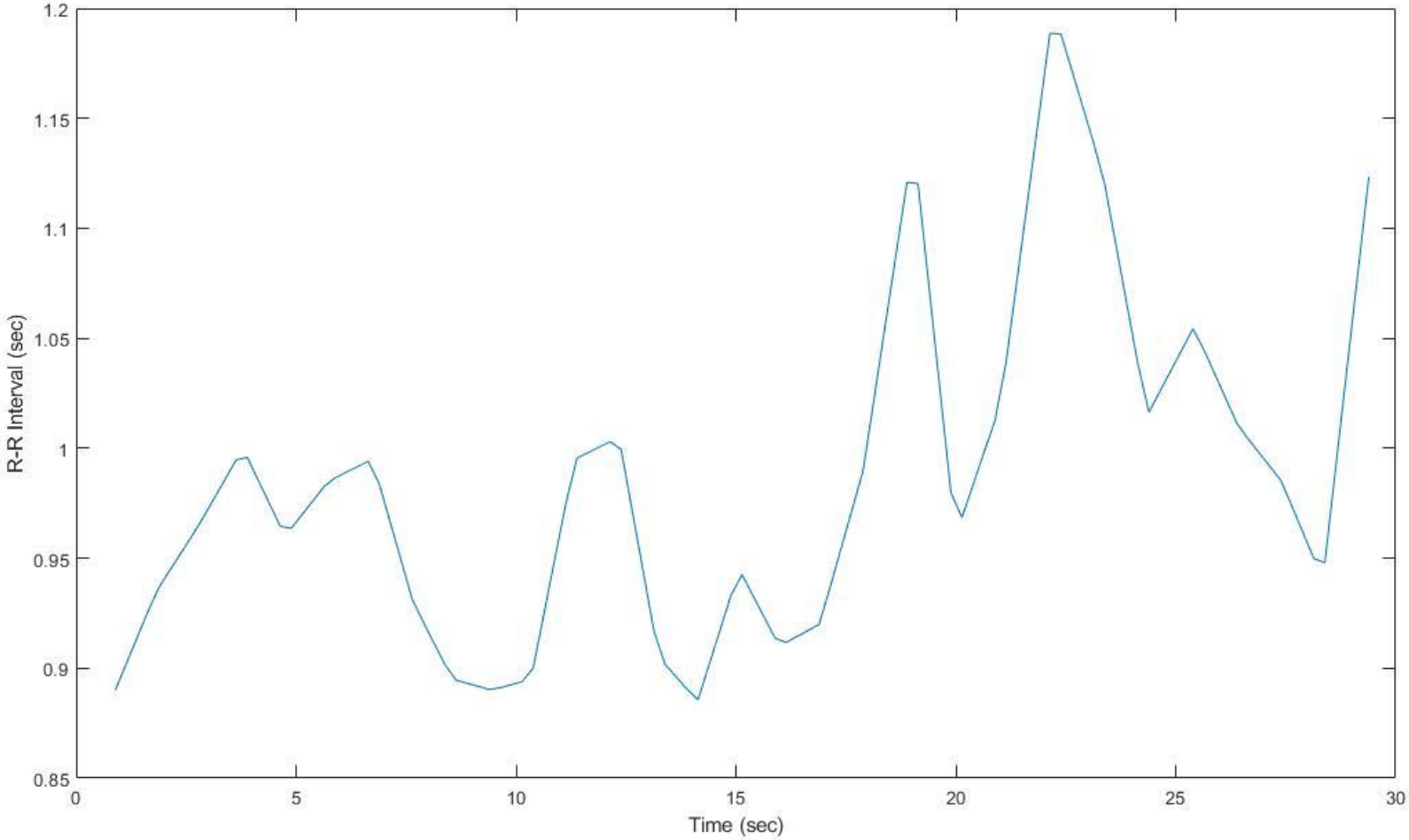
- rr = diff(locs)/200;



R-R Intervals Preprocessing

- t = cumsum(rr);
- tt = t(1):0.25:t(end);
- rr_resampled = interp1(t,rr,tt);
- plot(tt,rr_resampled)
- xlabel('Time (sec)');
- ylabel('R-R Interval (sec)');

R-R Intervals (Evenly Sampled)



Definition of Frequency Domain Measures

VLF (ms^2)	Total spectral power of all normal interbeat intervals between 0.003 and 0.04 Hz
LF (ms^2)	Total spectral power of all normal interbeat intervals between 0.04 and 0.15 Hz
HF (ms^2)	Total spectral power of all normal interbeat intervals between 0.15 and 0.4 Hz
LF/HF	Ratio of low to high frequency power

Task Force of the European Society of Cardiology.
Circulation 1996;93:1043-1065.

Question

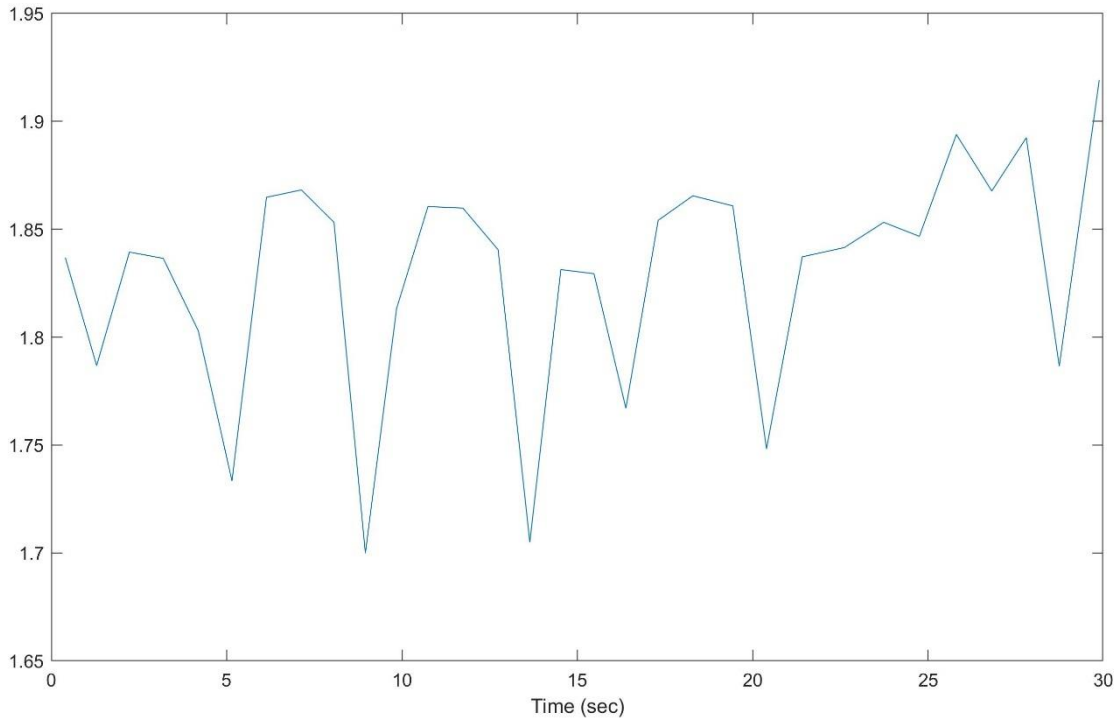
- How to calculate respiratory-related (high-frequency) power in a R-R interval signal?

Estimate Spectral Power of R-R Interval **Welch Method**

- [ps,fs] = pwelch(yy,hanning(length(yy)),0,length(yy),4);
- plot(fs,ps)
- axis([0.001 0.4 0 500000]);
- xlabel('Frequency (Hz)')
- ylabel('Power Spectral Density (ms2/Hz)')
- title('R-R Power Spectral Density Plot')

Extract ECG-derived Respiration Signal

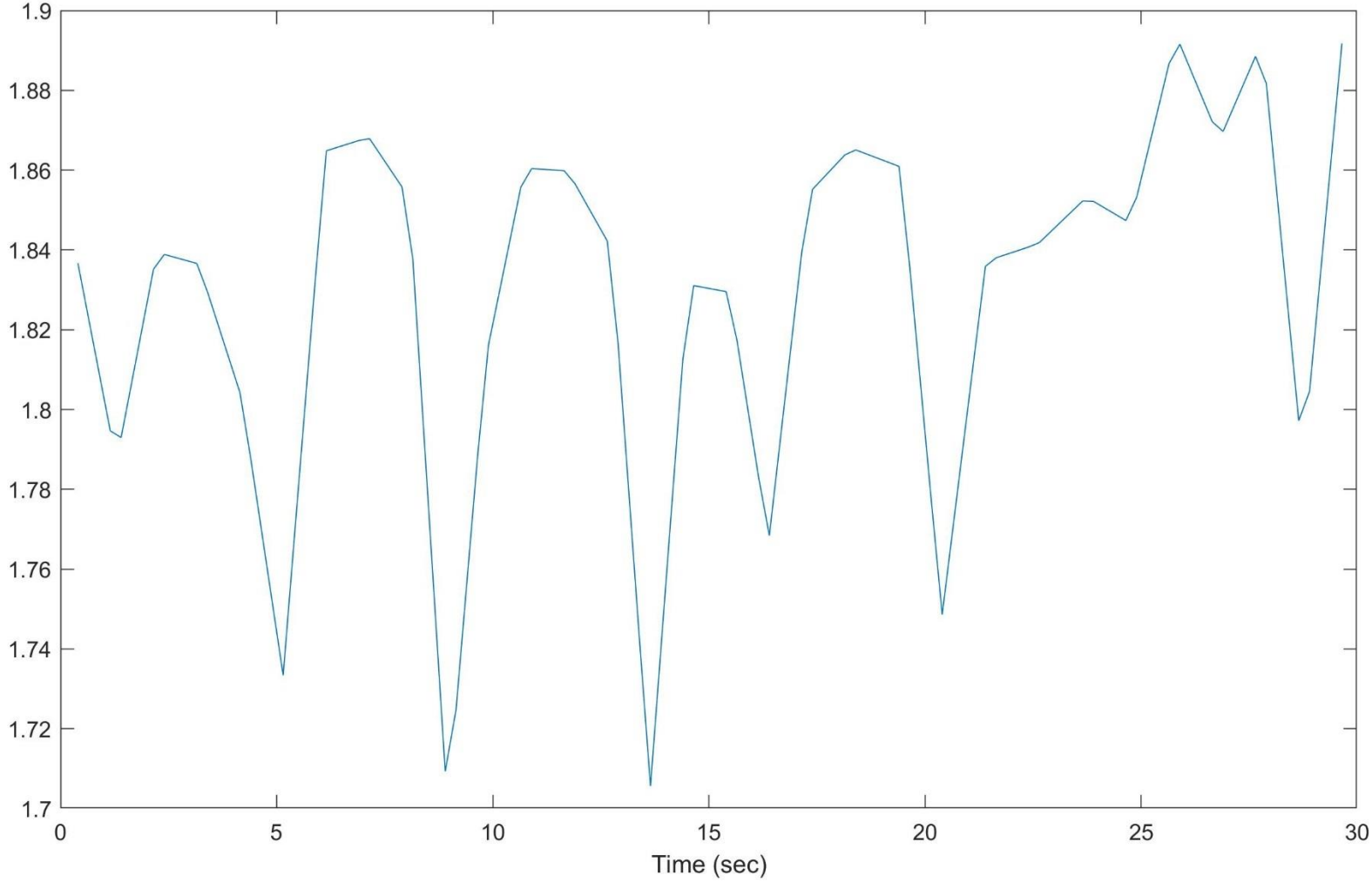
- plot(locs/200,pks)
- xlabel('Time (sec)');



Extract ECG-derived Respiration Signal

- tt = locs(1)/200:0.25:locs(end)/200;
- edr = interp1(locs/200,pks,tt);
- plot(tt,edr)
- xlabel('Time (sec)');

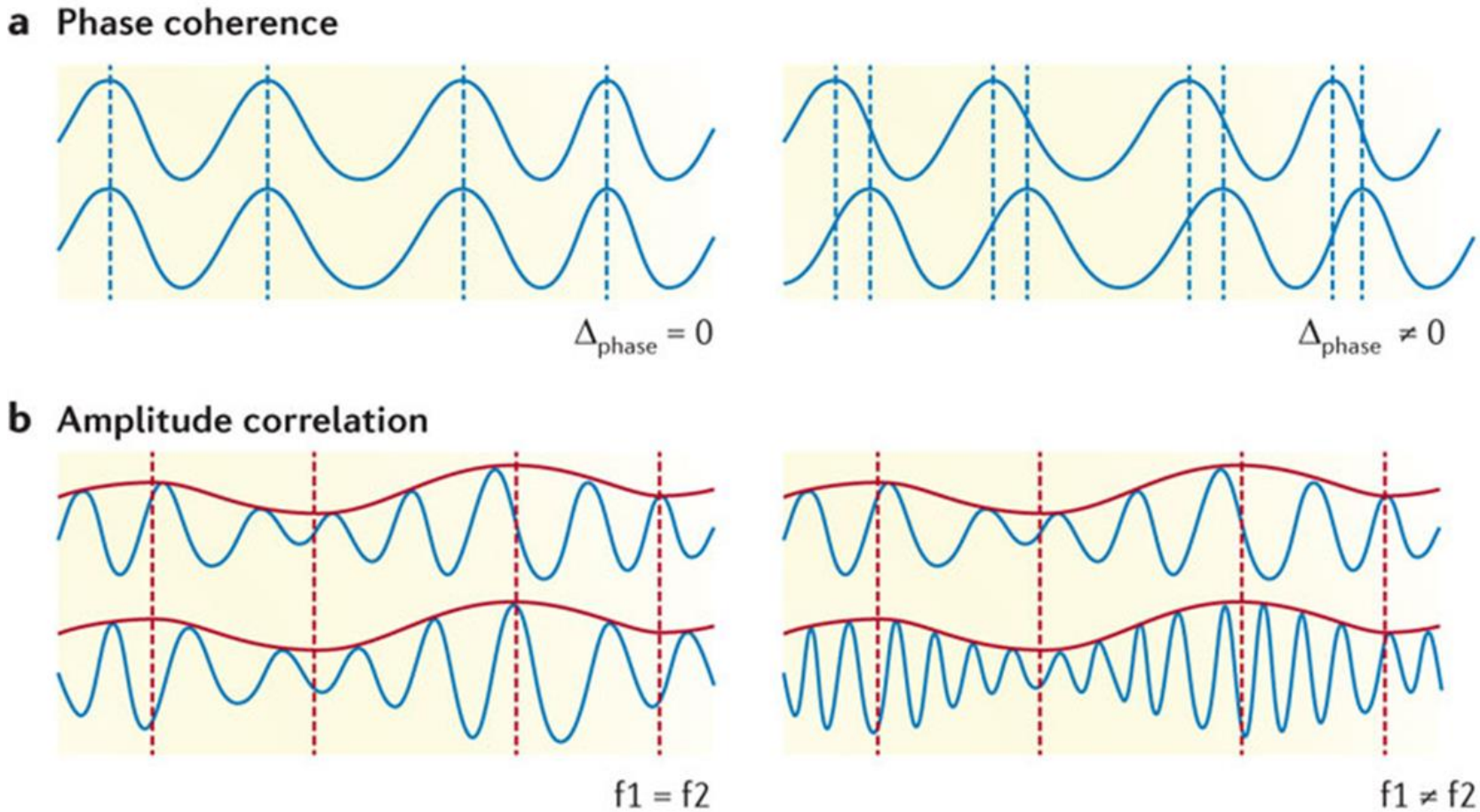
ECG-derived Respiration (EDR) Signal



Question

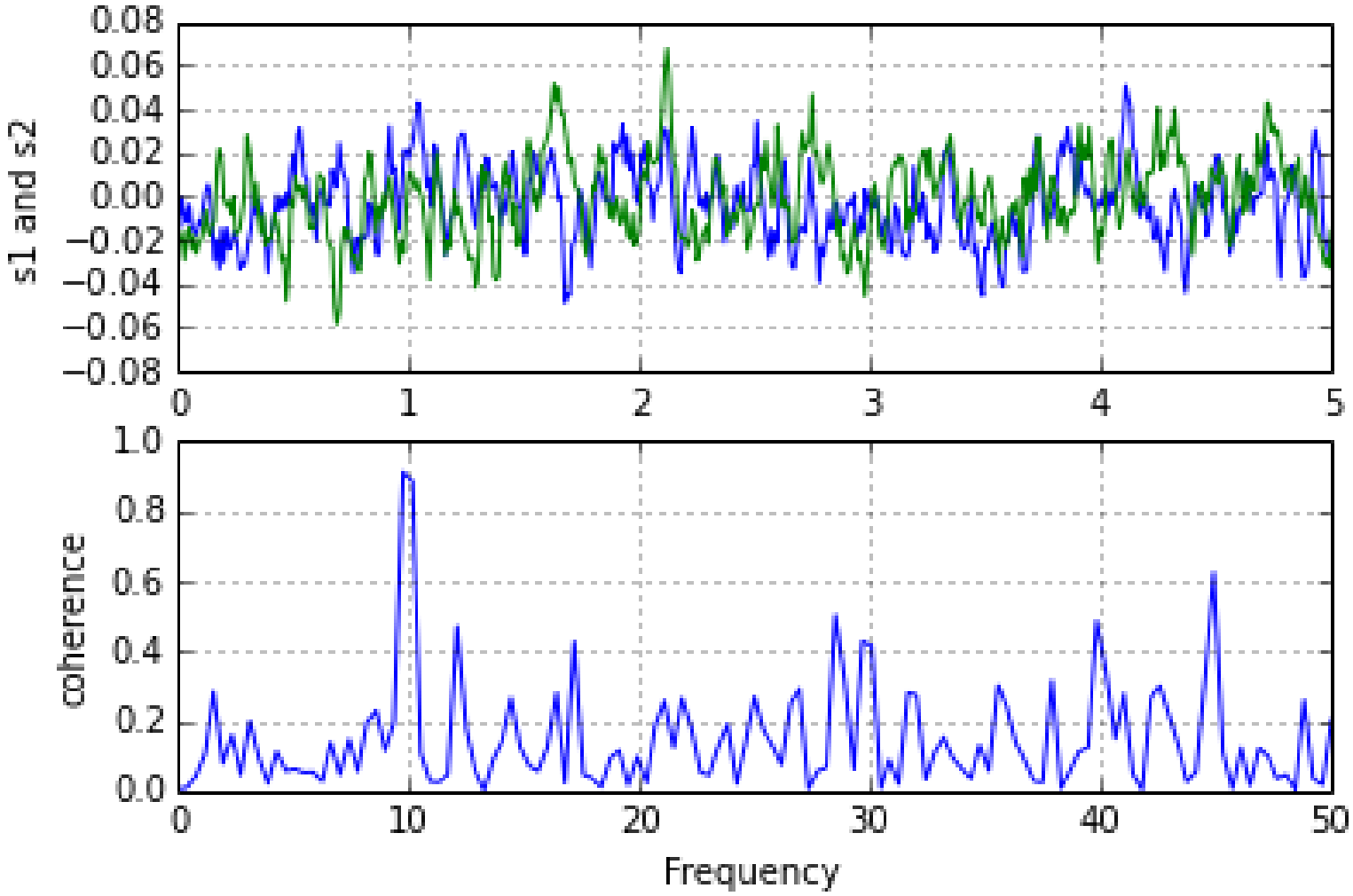
- How to calculate respiratory power in an EDR signal?

Correlation vs. Coherence



Siegel M et al. **Nature Reviews Neuroscience** (2012)

Spectral Coherence



Question

- How to calculate coherence between R-R interval and EDR signal?
- How to determine high-frequency coupling and low-frequency coupling