Oscillation around non-stationary equilibria

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Introduction

Major components of the autonomic nervous system include

- Sympathetic nervous system (SNS) – responding to stress
  - increases cardiac output
  - increases oxygen flow
  - increases blood glucose levels
- Parasympathetic nervous system (PNS)
  - restorative
  - homeostatic functions

Introduction

Frequency analysis of heart rate variability (HRV)

- .15-.40 Hz = high frequency band (HF), associated with PNS
- .04-.15 Hz = low frequency band (LF)
  - Associated with SNS, but
  - Contains some influence from PNS, hard to disentangle

Participants

121 mothers and their 17- to 19-month-old children

- Socioeconomically diverse
- Mothers were between ages 18 and 42 ($M = 24$)
- Median family income \$40,000 a year
- $\frac{1}{3}$ reported earning less than \$23,000 a year

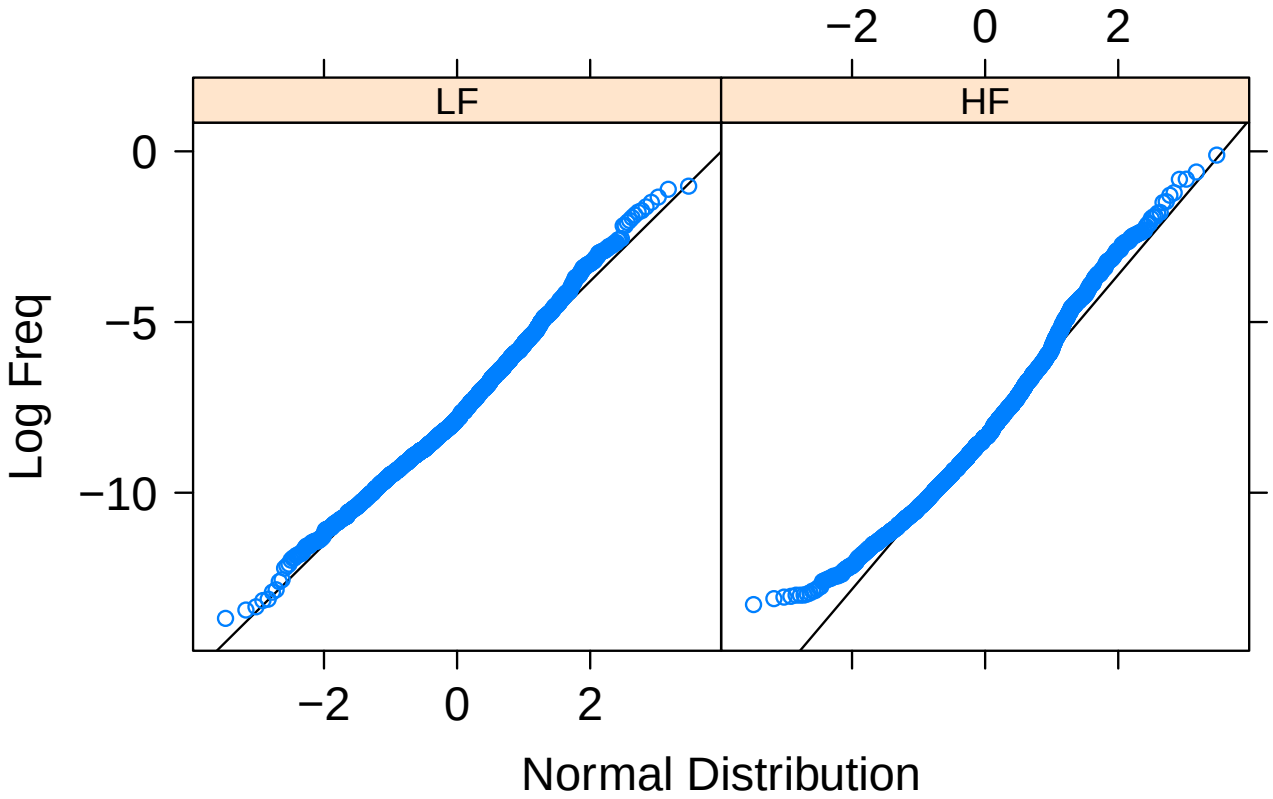
Participants

Table: Ethnic breakdown of participants

Ethnic Identity	Mothers	Children
European-American	55%	49%
African-American/Black	26%	25%
Latino	11%	12%
Biracial	5%	14%
Asian	$< 1\%$	0%
Native American/Alaskan	$< 1\%$	0%

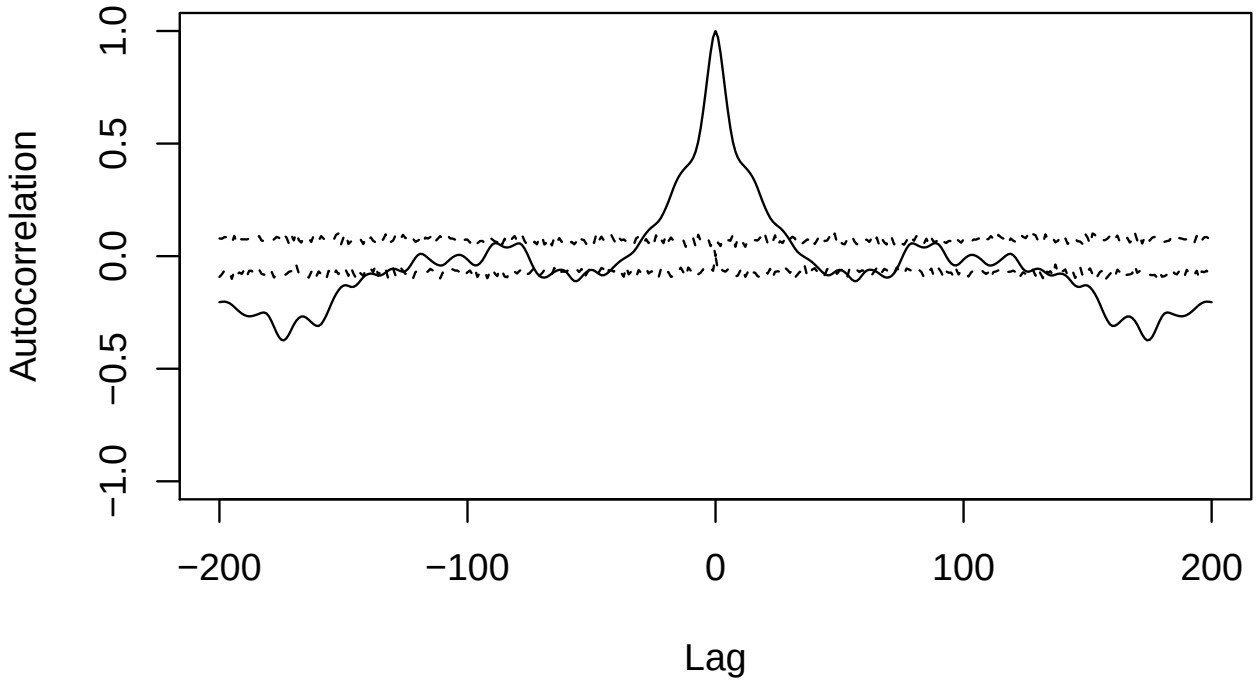
Results

A log transformation was applied to HF and LF heart rate data to compensate for positive skew.



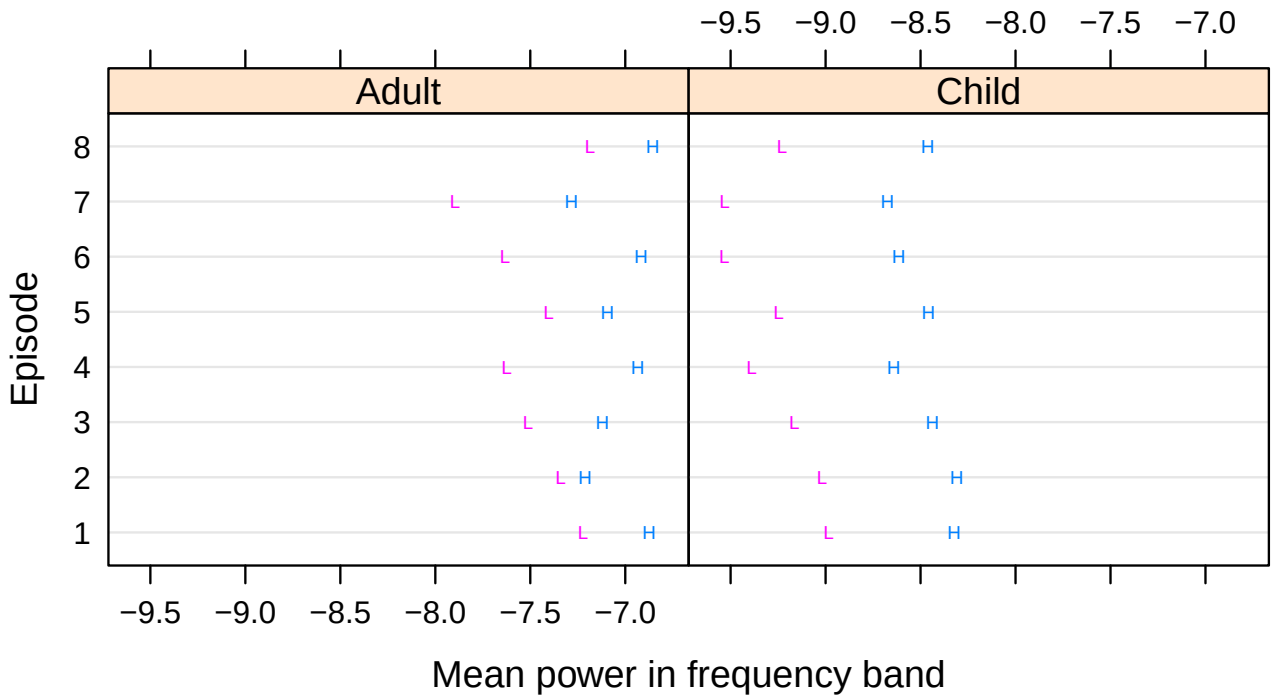
Results

The autocorrelation function was used to check for time dependence (Adult 2460, LF band).



Results

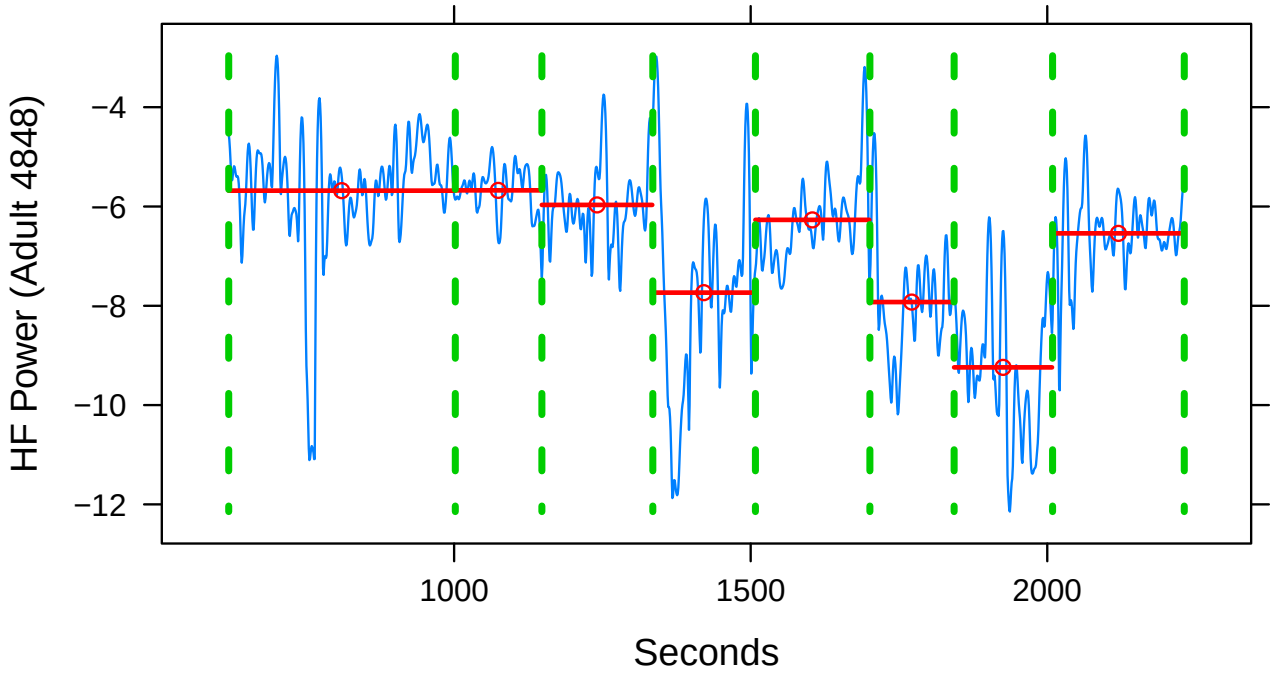
Mean power varied by episode.



Note: Episode 1 was acclimation to the observation room.

Results

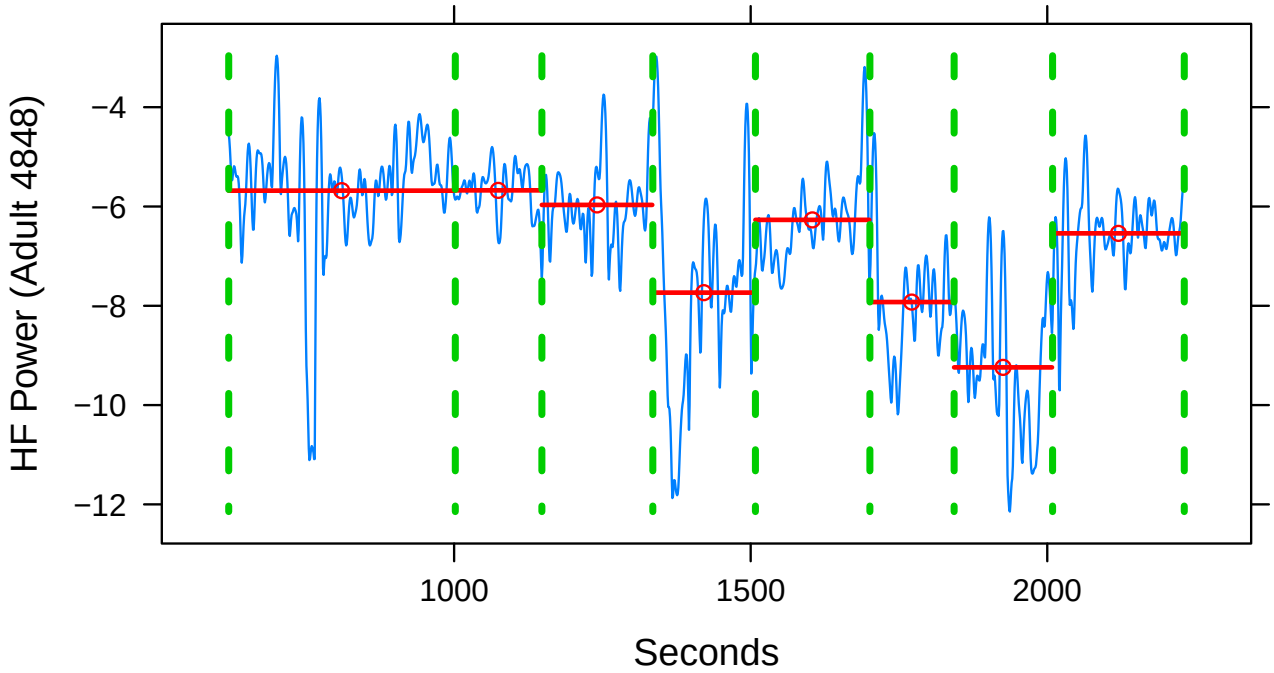
Mean power varied by episode. An example.



An oscillation of 32 s period around a non-stationary equilibrium?

Results

Mean power varied by episode. An example.

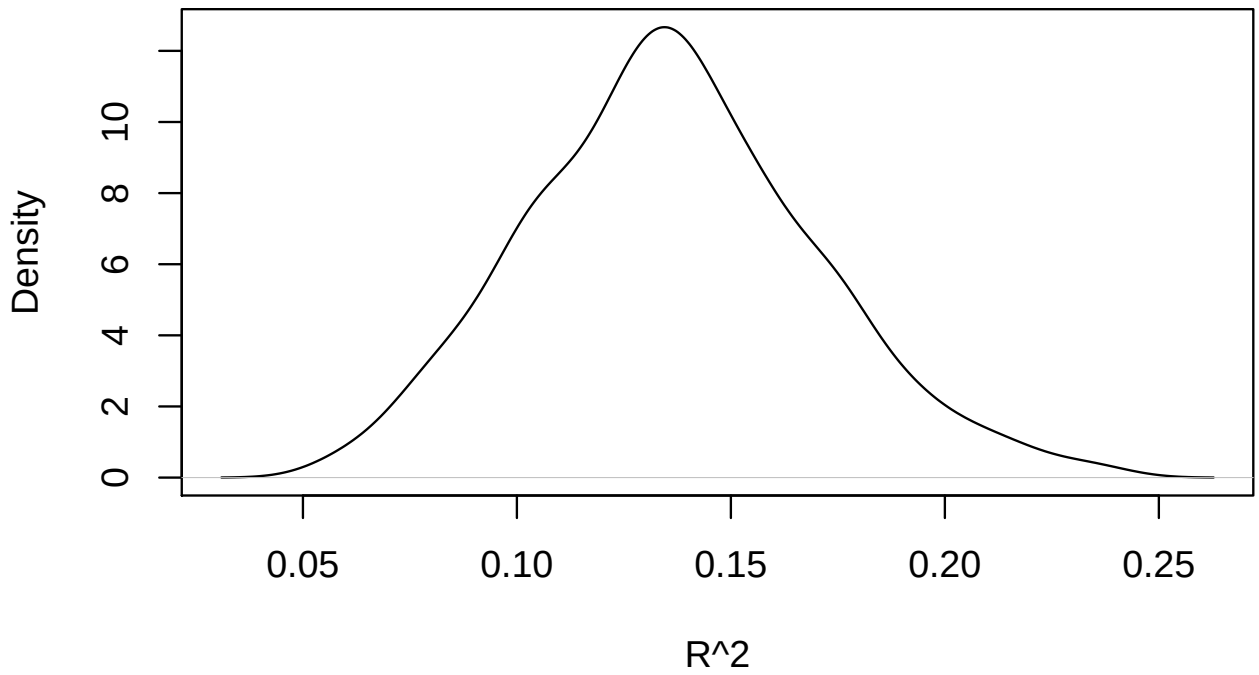


An oscillation of 32 s period around a non-stationary equilibrium?

Results

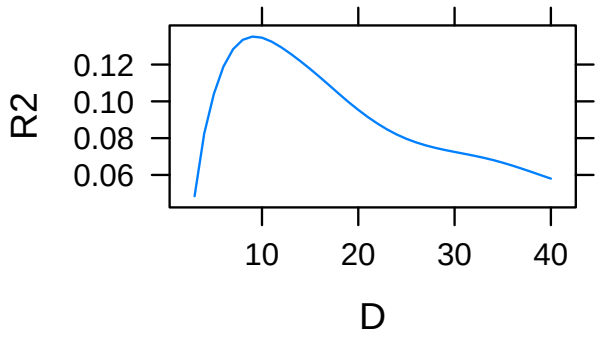
Generalized Orthogonal Linear Derivatives (GOLD) permit the estimation of derivatives from discrete measurements.

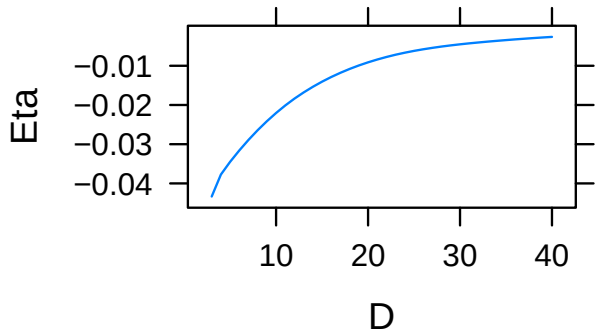
Maximum 2nd degree GOLD R^2 for embedding dimensions between 3 and 40 with equilibrium centered at the mean of the first episode

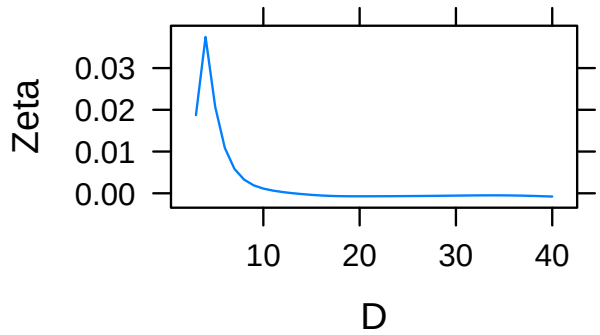


Results

Typical 2nd degree GOLD fit

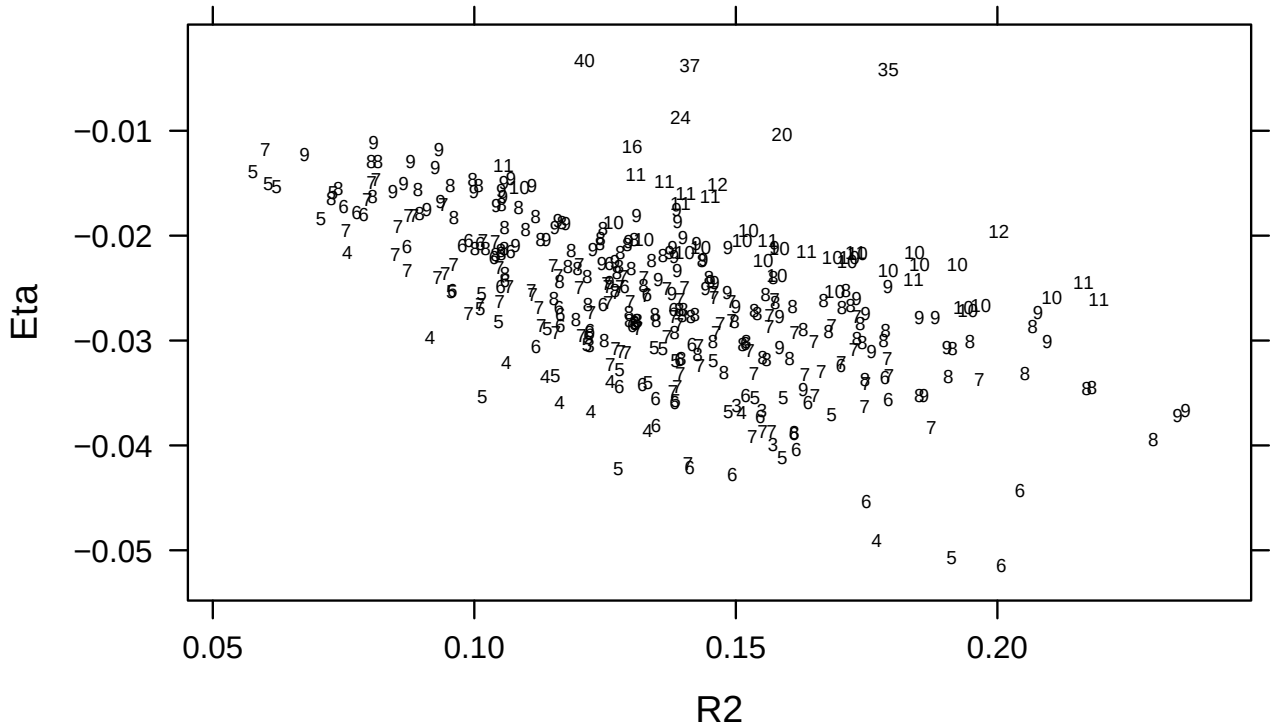






Results

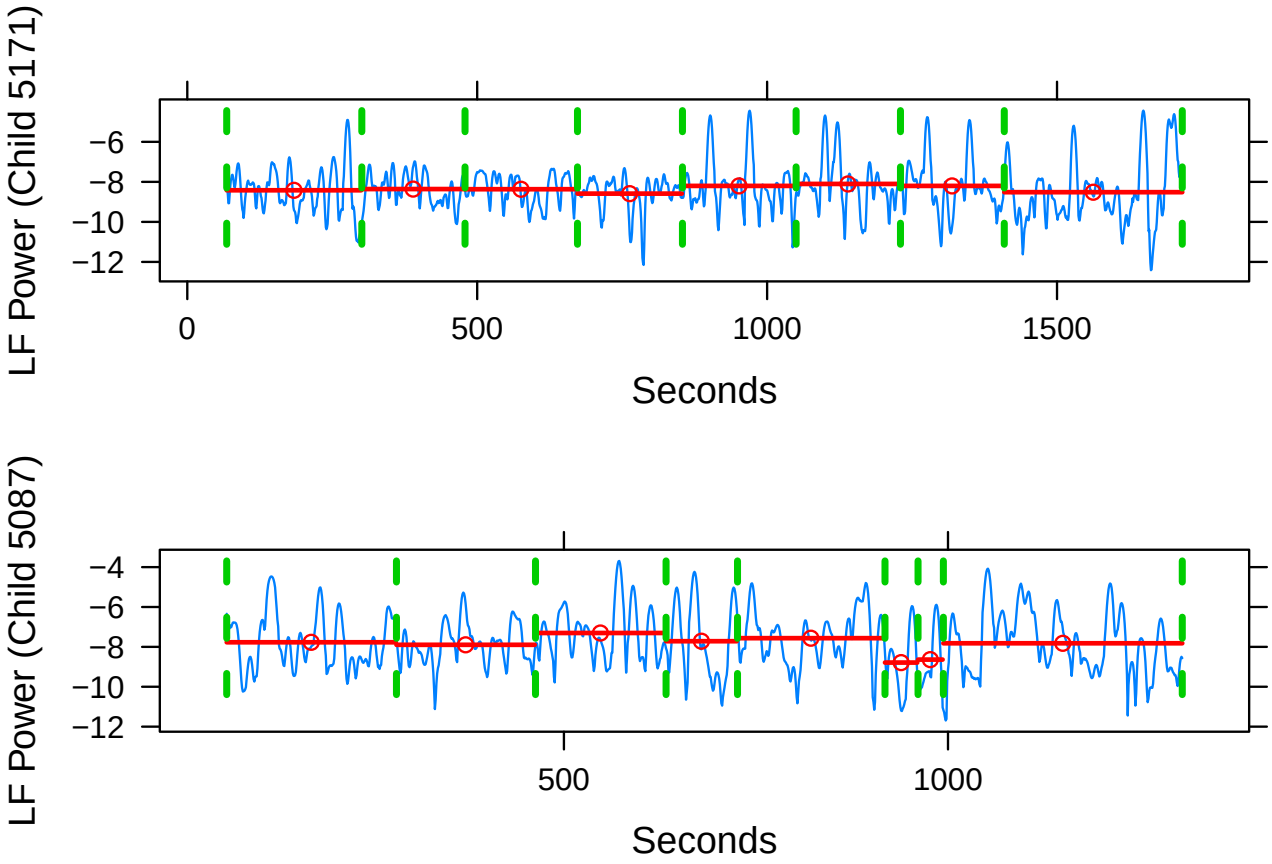
Eta vs R^2 vs Embedding dimension



Eta is the first derivative estimate.

Results

Participants with best fit for 2nd degree GOLD embedding



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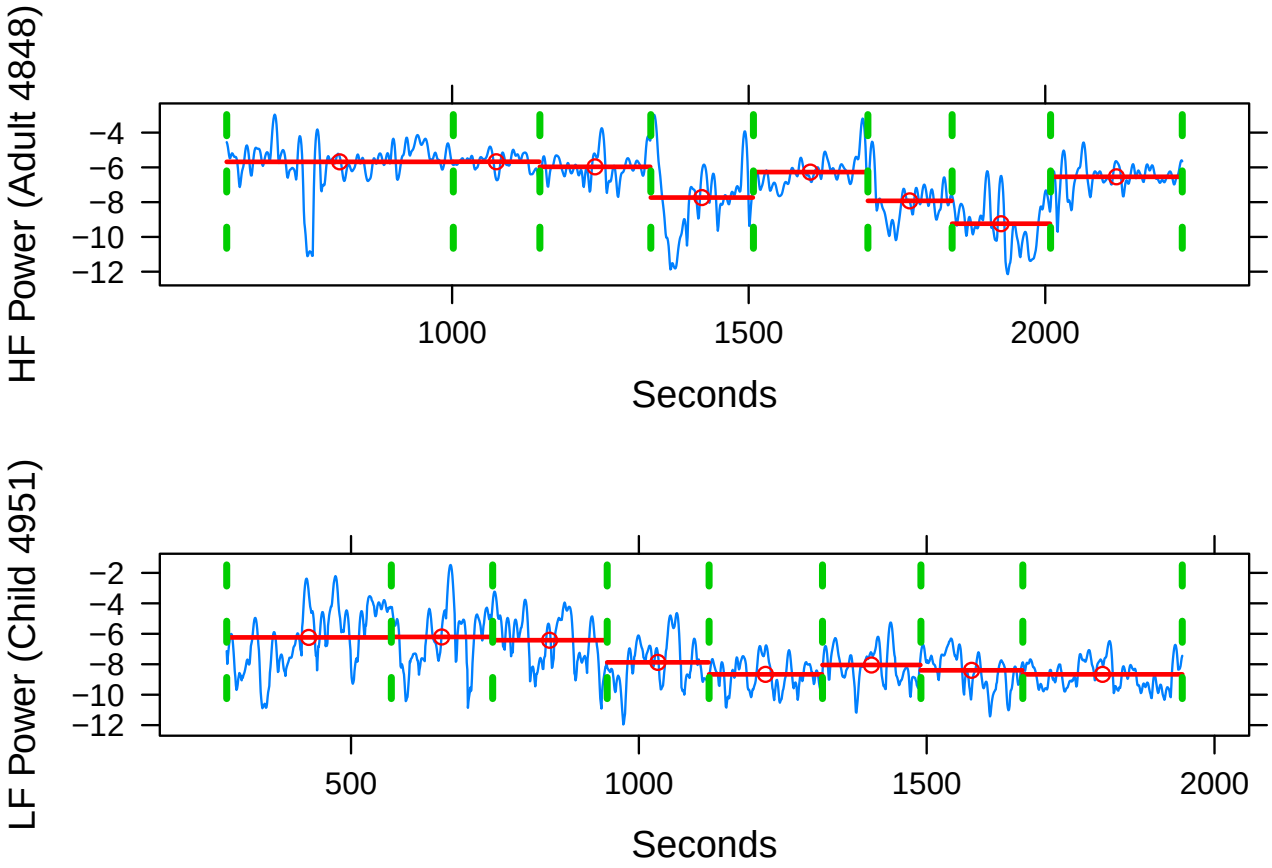
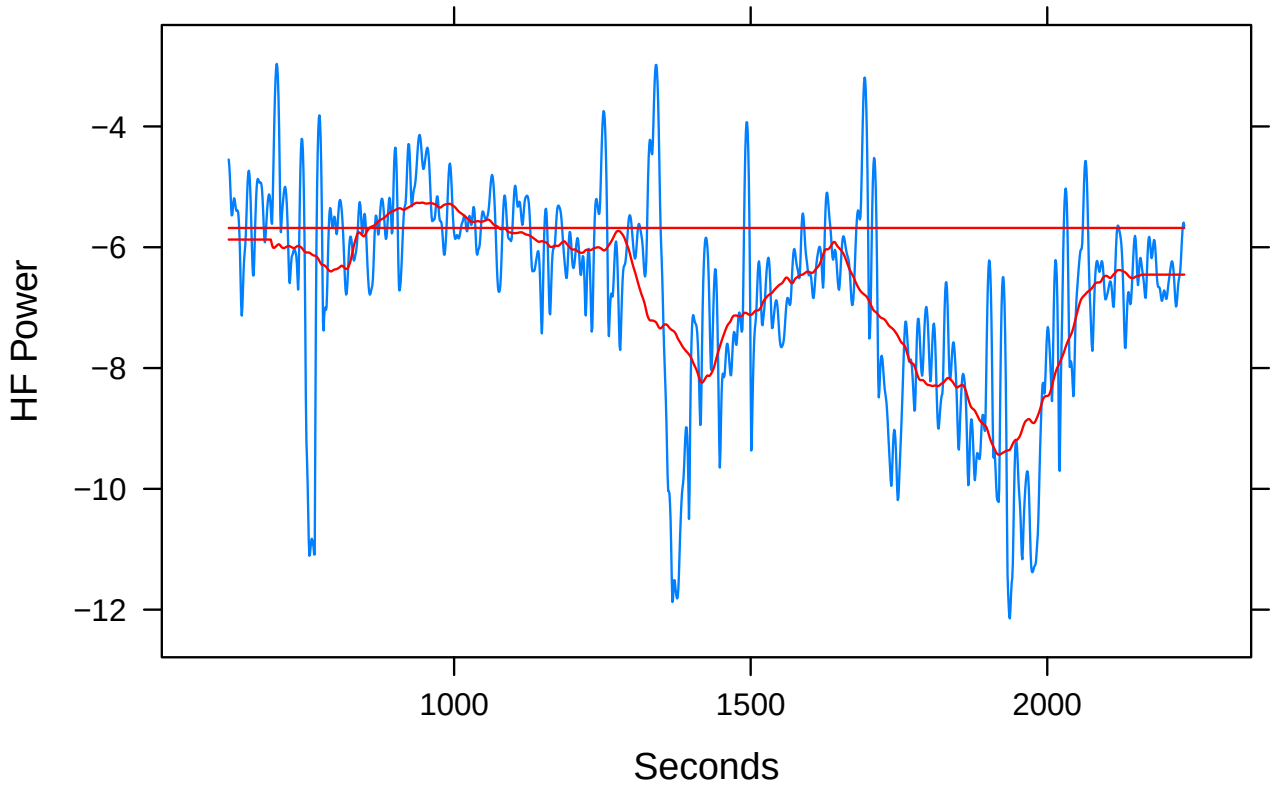


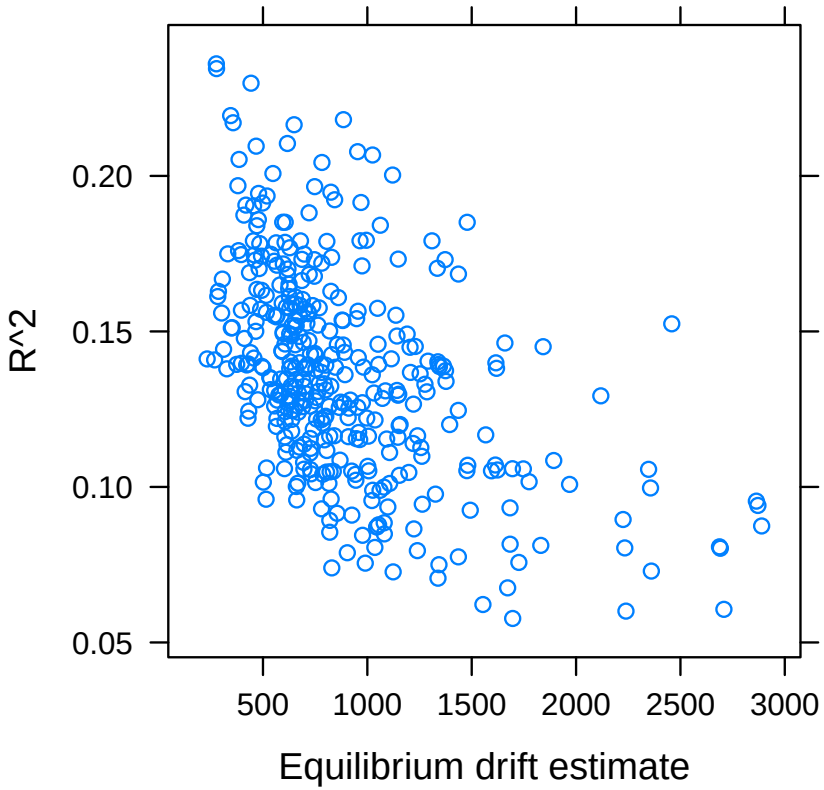
Results

How to measure equilibrium drift? How about the sum of the absolute value of the 144 s moving average minus the mean of episode 1?



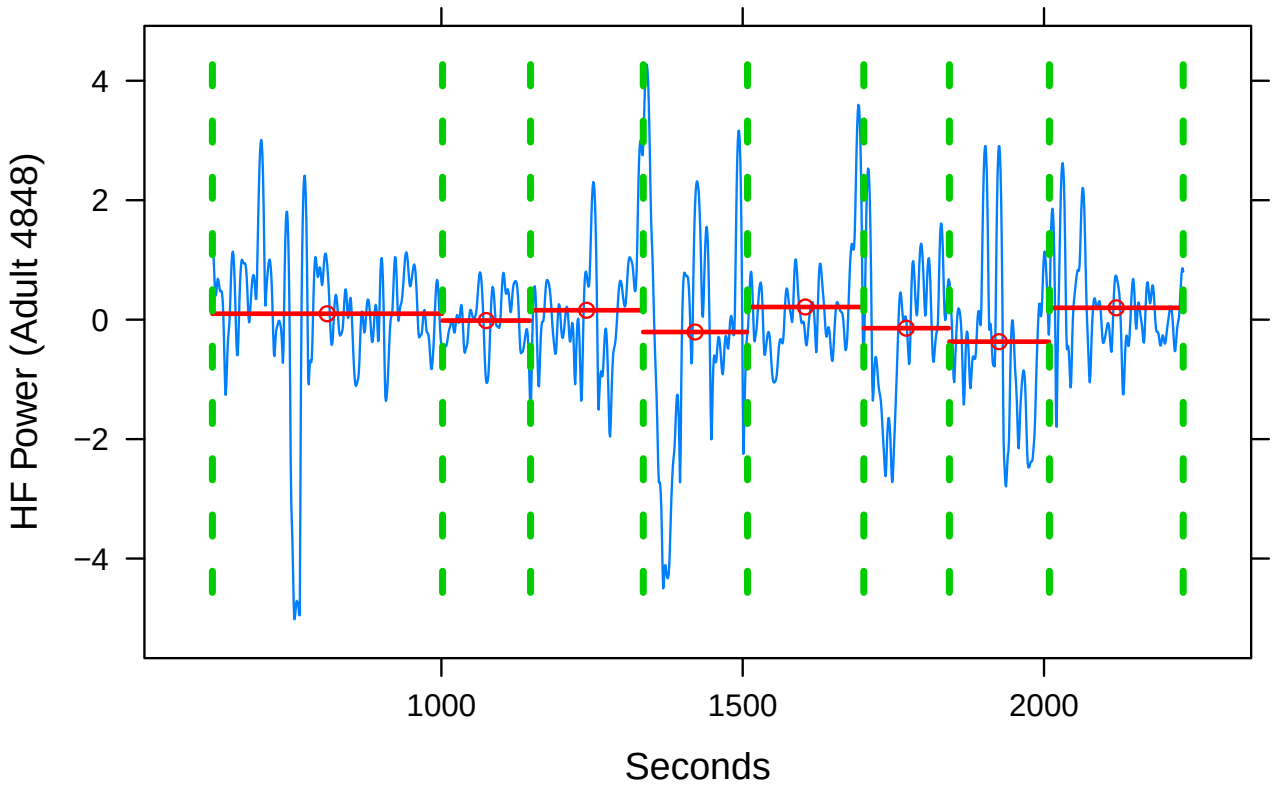
Results

R^2 and equilibrium drift were strongly correlated, $r(377) = \text{-}.49$, $p < .001$



Results

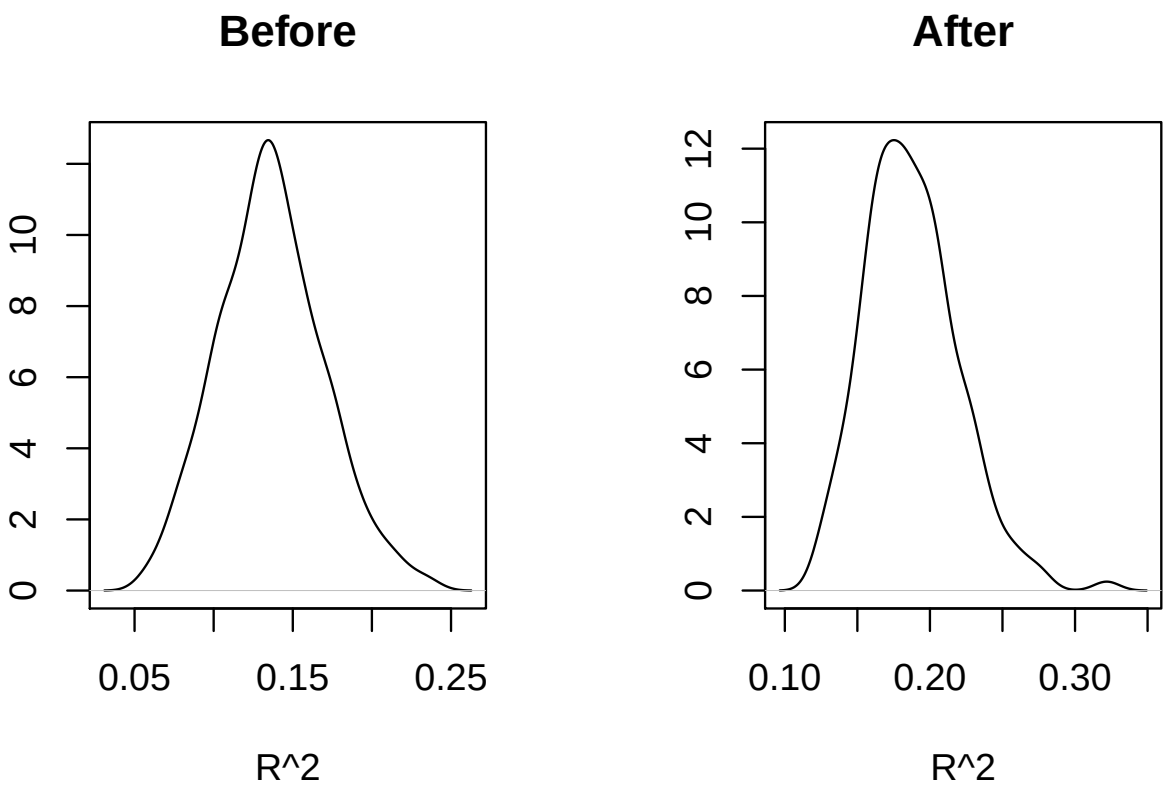
What does a time series look like after subtracting the moving average?



Note: This consumes 1 df (?)

Results

Maximum 2nd degree GOLD R^2 for embedding dimensions between 3 and 40 with equilibrium centered using a moving average



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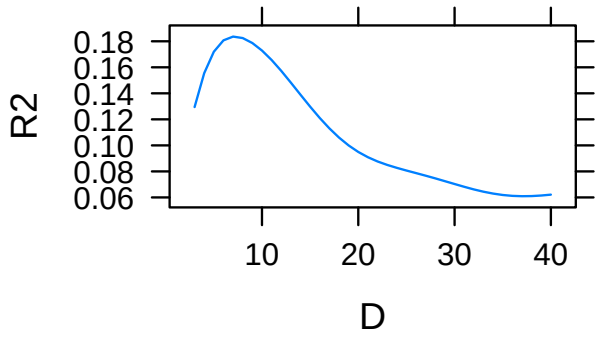
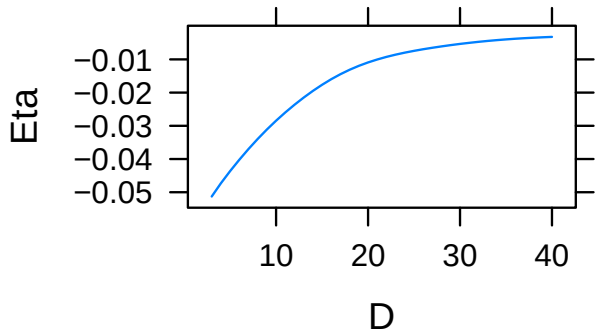
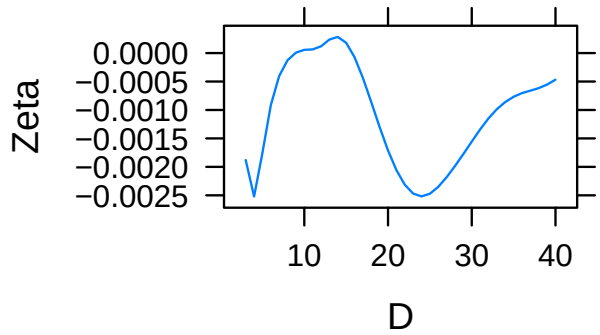
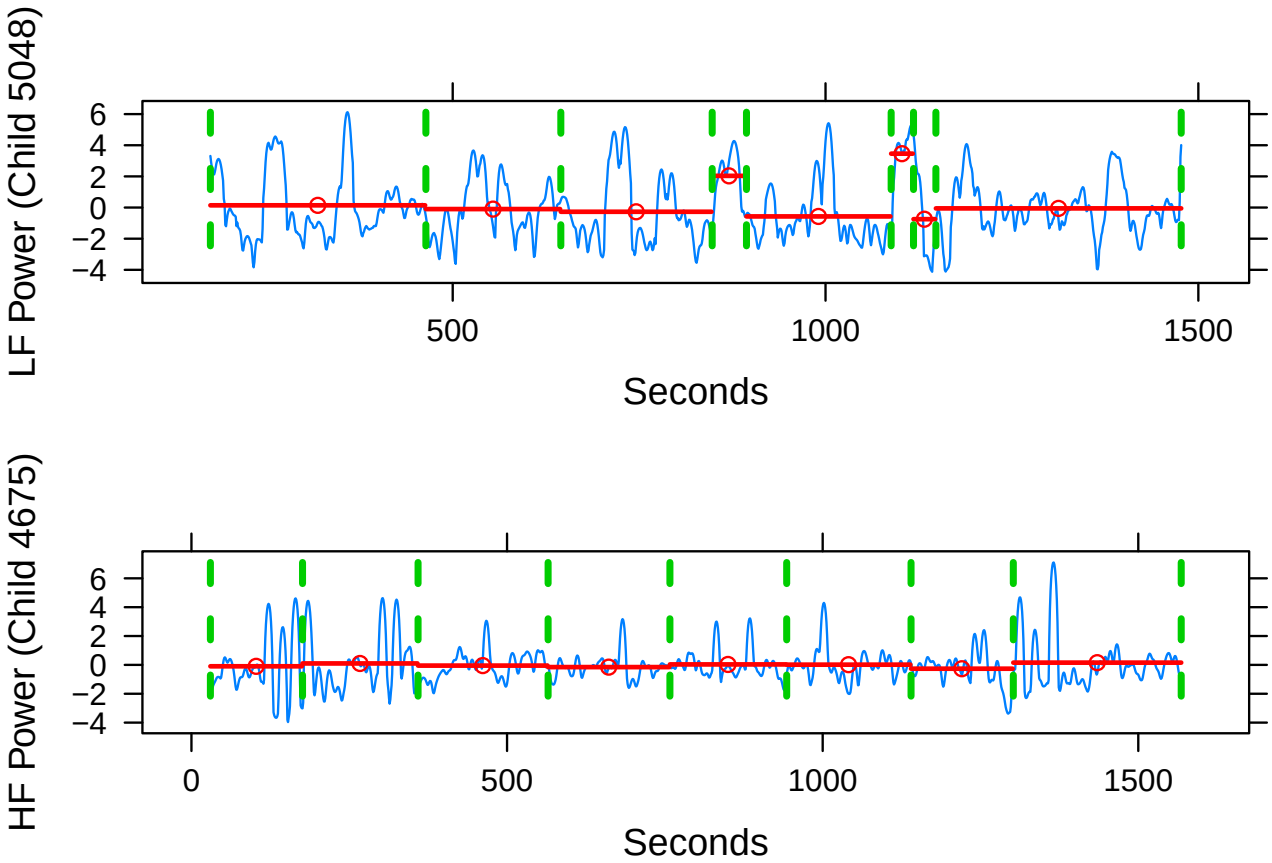






Results

Participants with best fit for 2nd degree GOLD embedding after subtracting the moving average



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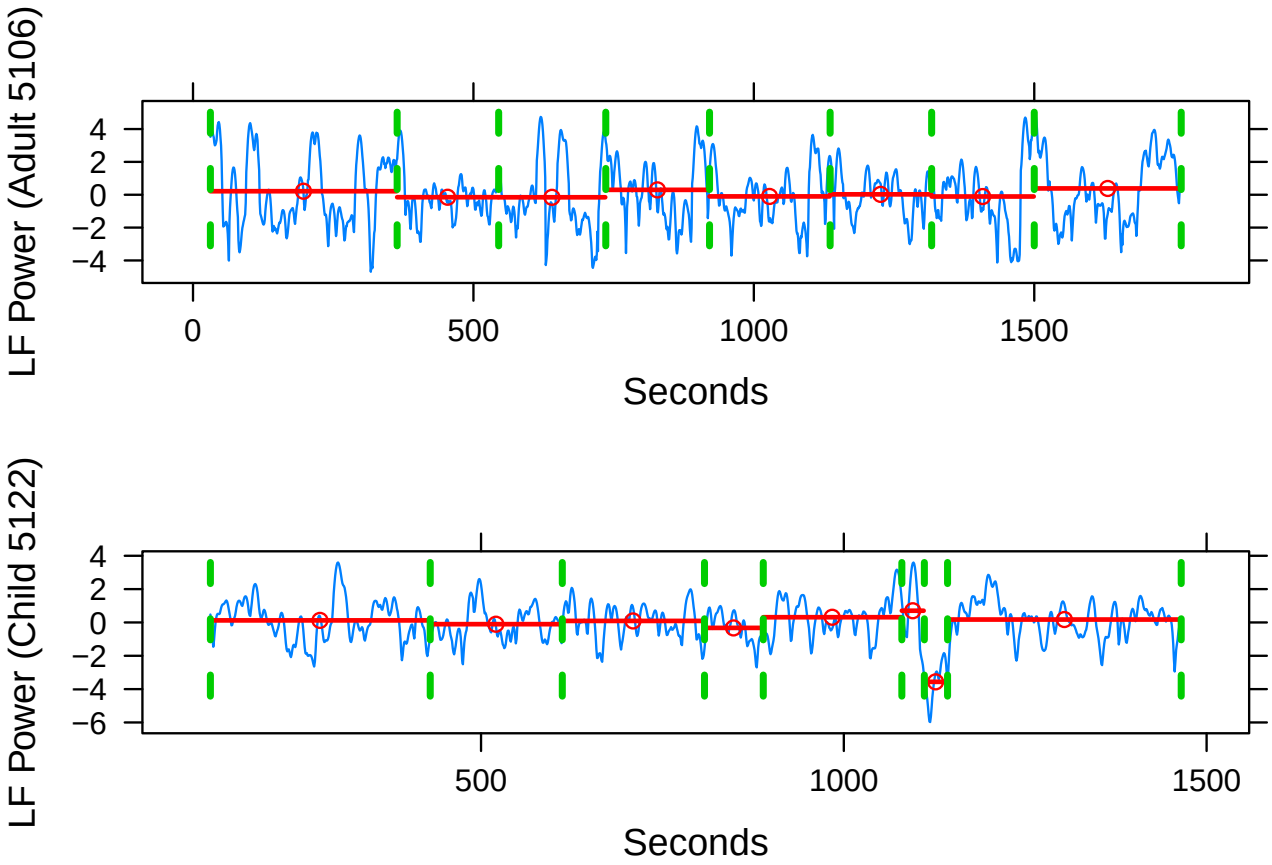
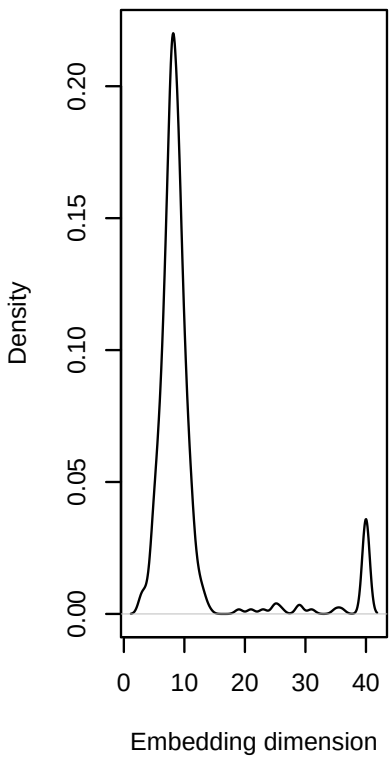
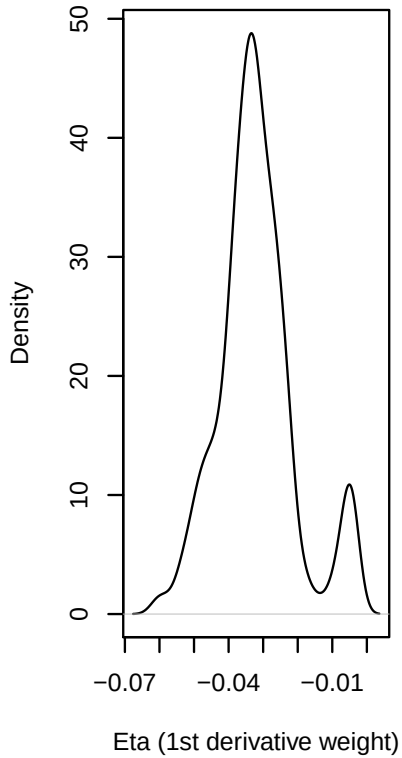
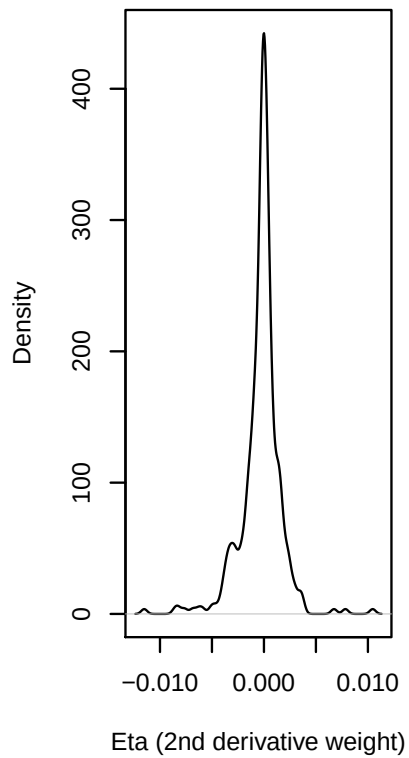


Results

Median embedding dimension $= 8$. Median $eta = -.033$. Median $zeta \approx 0$.







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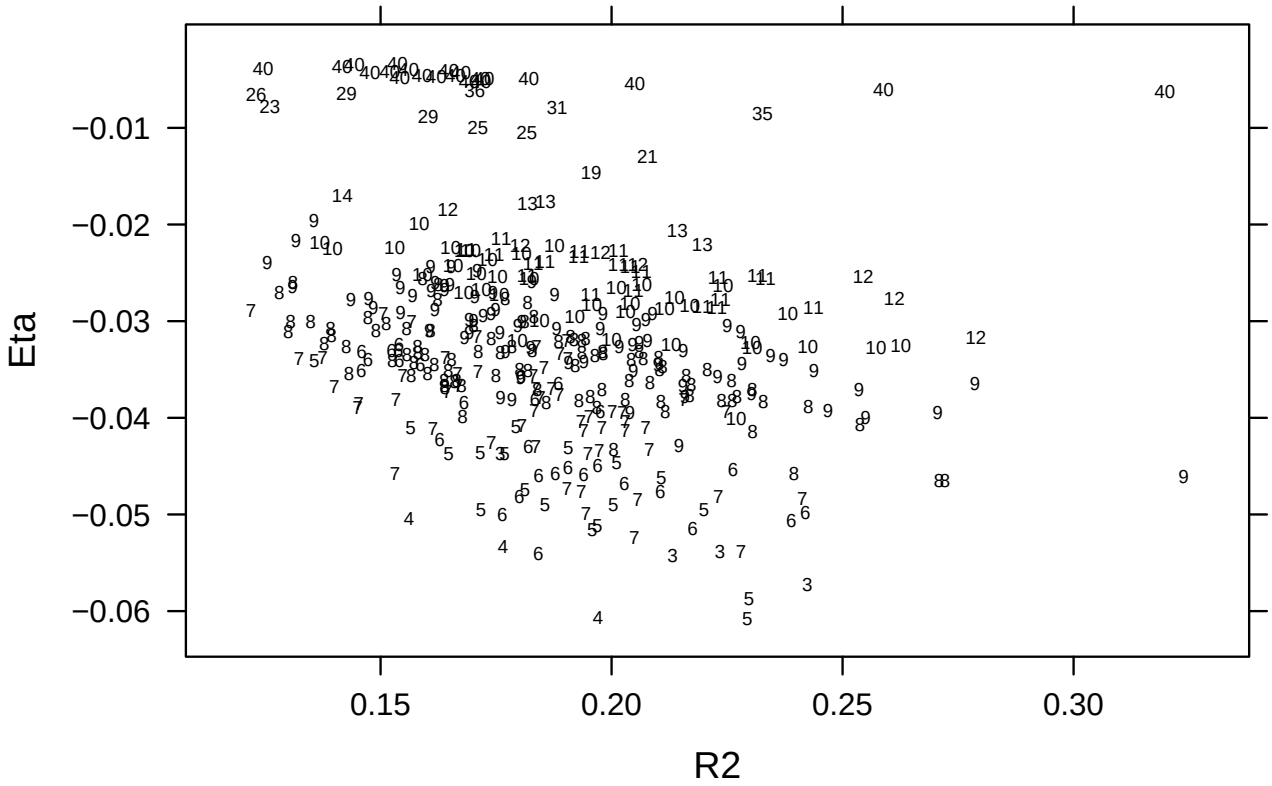
Eta vs R^2 vs Embedding dimension



Conclusions

- Ignoring dynamics and averaging band power over arbitrary time-windows result in unreliable estimates.
- Nonstationary equilibria wreck havoc on derivative estimates.
- Caution: Compensating for a nonstationary equilibrium will affect derivative estimates.

Future Directions

- Consider other filters (FFT, midpoints between peaks, many other variations of moving average, etc)
- Multivariate models, cross correlation, etc
- Theory must guide analysis!

Acknowledgments

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