

ENTROPIES OF THE EEG: The effects of general anesthesia.

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Rationale: Why bother with EEG Entropy Estimators?

- The formation and dissolution of cortical microstates = 'Corticodynamic' entropy
- Limitation of microstates \equiv lower entropy
- Lower entropy \equiv unconsciousness

QUESTIONS

- (1) Is the EEG telling us about the Cortex?
- (2) Are Entropy Estimators wrecked by artifacts?

Entropy Bestiary

- Spectral Entropies

- Spectral Entropy (1:47Hz)
- Renyi Entropies
- Kullback-Leibler (=Relative entropy)
- CUP
- Fisher I
- Wavelet
- HOS
- Tallis (q)

- Embedding / Phase-space Entropies

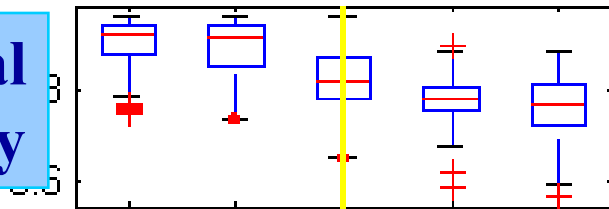
= Kolmogorov-Sinai

- Approximate Entropy and Cross ApEn
- Singular Value Decomposition Entropy

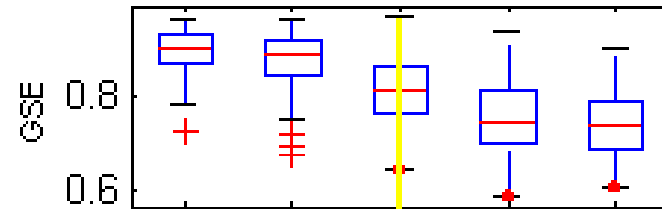
Patient data: Induction of Anesthesia

Boxplots (median +/- IQR) of changes in various EEG measures during induction in 60 patients

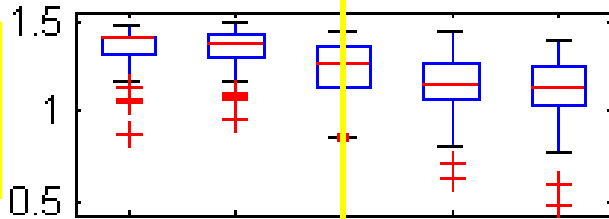
Spectral Entropy



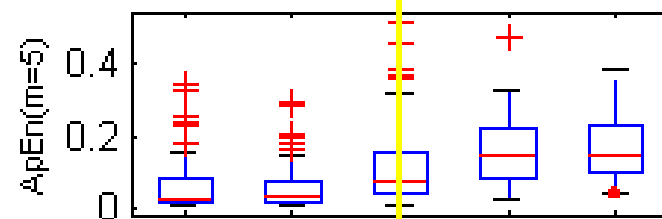
Renyi: GSE



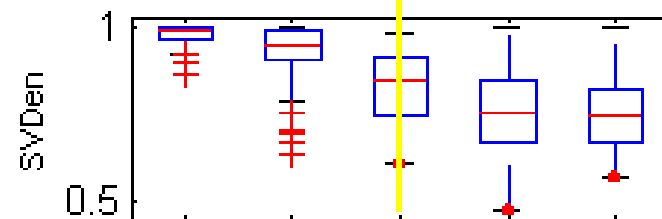
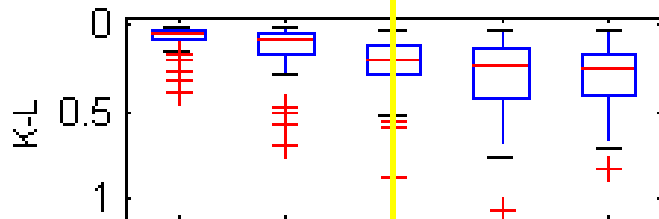
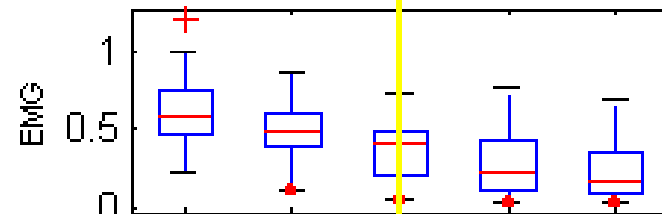
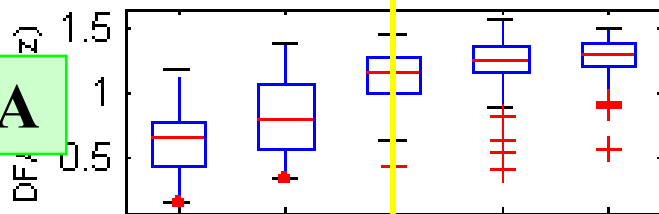
ApEn (m=2)



ApEn (m=5)



DFA



Start -15 LOC +15 +30
AWAKE Time(s) **ASLEEP**

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AWAKE Time(s) **ASLEEP**

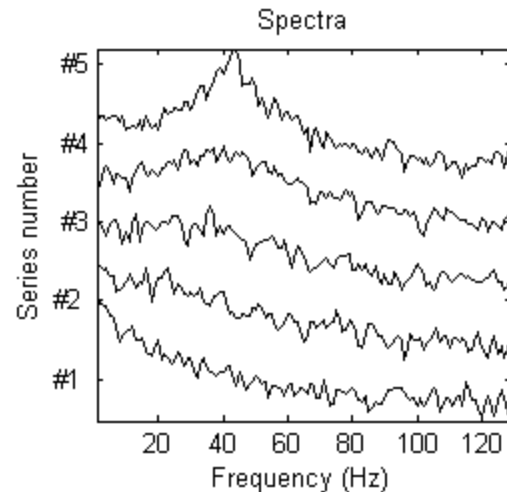
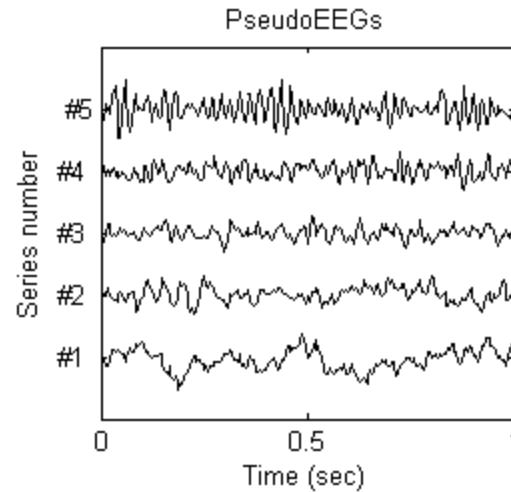
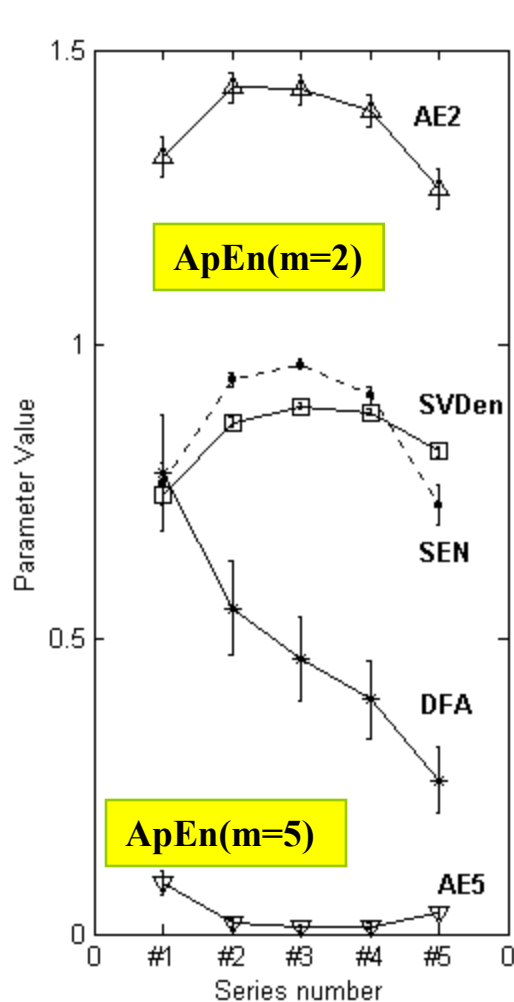
SVDen

(Q). Why are the entropy estimators “sort-of-the-same” but “sort-of-different”?

(A). See how they perform with controlled “PseudoEEG” signals

- 1) AR2 model
- 2) White noise + artifacts
- 3) Real EEG + oscillations

(1) Pseudo-EEG series (AR2)

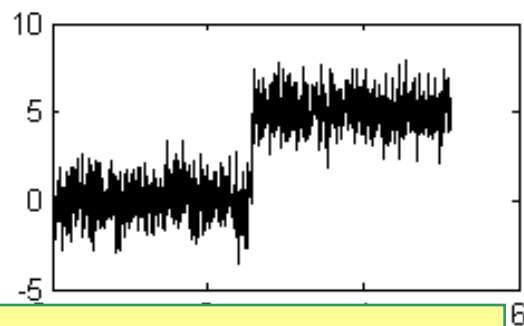
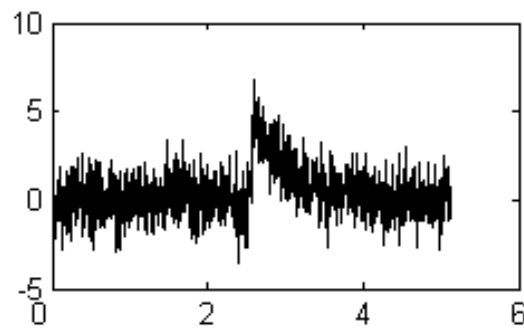
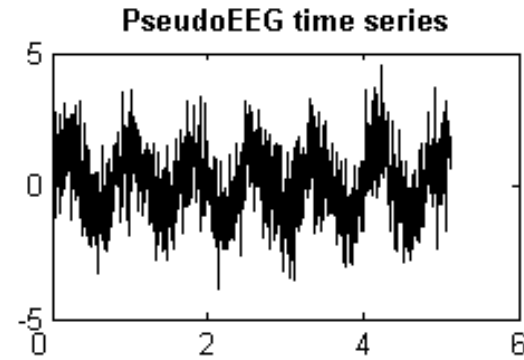


(1) **Decreased** by shift to Low-frequency power and Oscillations.

< ??EXCEPT DFA ??>

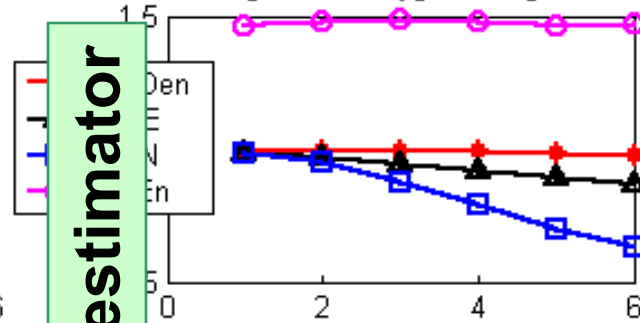
(2) ApEn(m=5) and ApEn(m=10) go the **opposite direction** to ApEn(m=2).

(2) Are the differences just sensitivity to artifact?



Raw 'pseudoEEG' Series

Change in entropy vs magnitude



ApEn

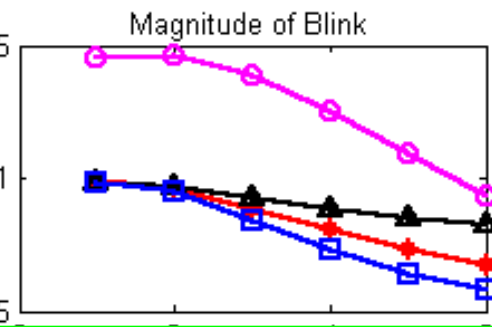
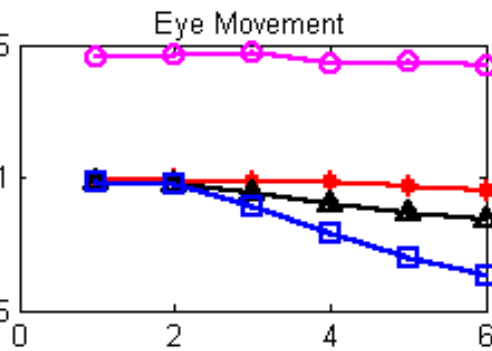
SVDen

GSE

Spectral

Entropy

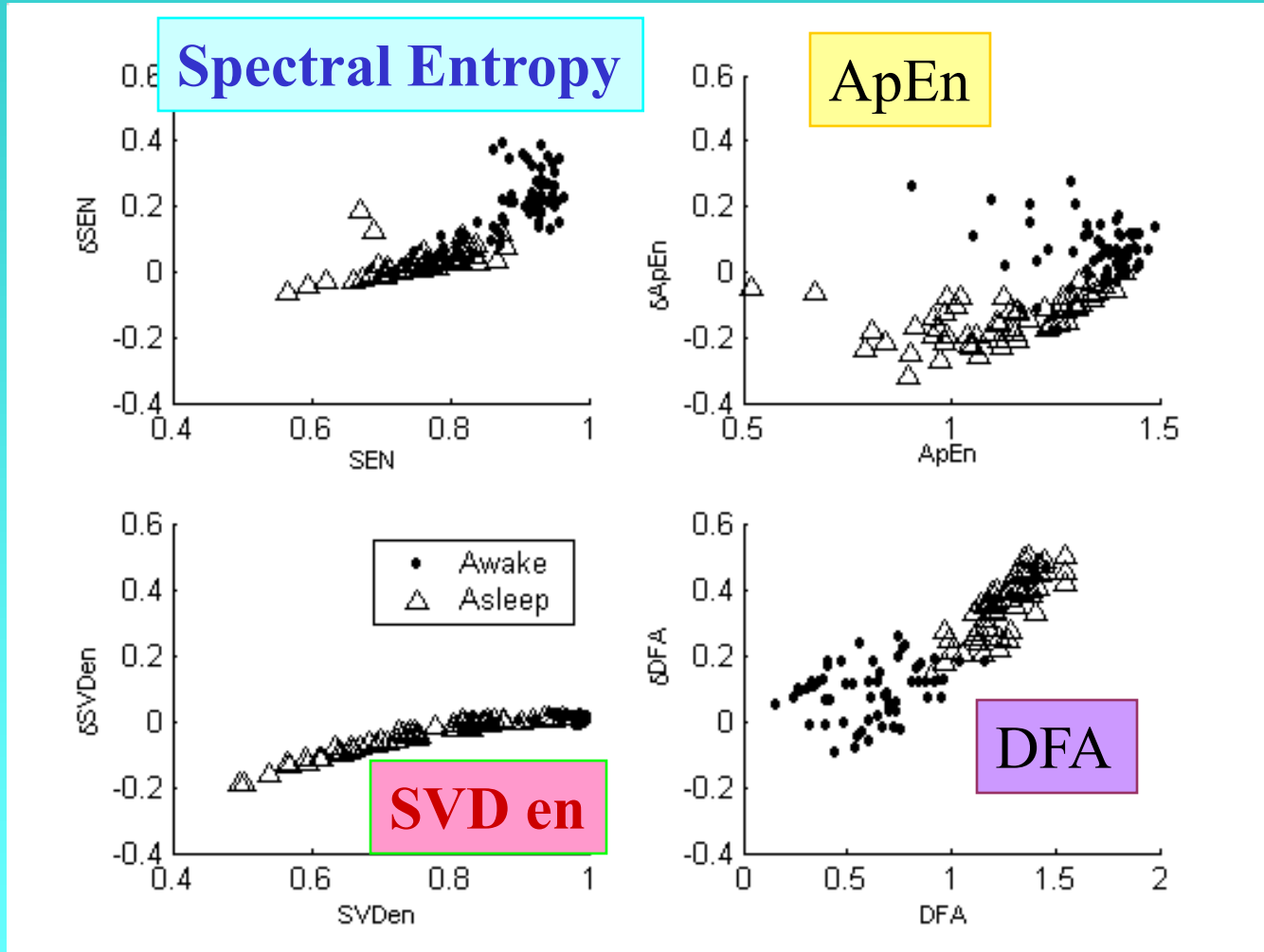
Change in Entropy estimator



Magnitude of Artifact

(3) The effects of oscillations: Patient data

Difference in Parameter (raw-osc)



Value of parameter

Conclusions...

- **(1a)** Anesthetics “**make the EEG less free**”...
- **(1b)** The EEG changes \approx Corticodynamic entropy...

- **(2a)** Entropy estimators \equiv Correlation-Time estimators... [*DFA; ApEn(m=2) \neq ApEn(m=5)*]
- **(2b)** Sensitivity to artifacts \propto to underlying EEG signal... [*SEN > GSE > SVDen, ApEn*]