

Summit on Systems Biology 2007

Workshop II: Clinical Science Part C: Complex Patterns of Abnormal Heartbeats

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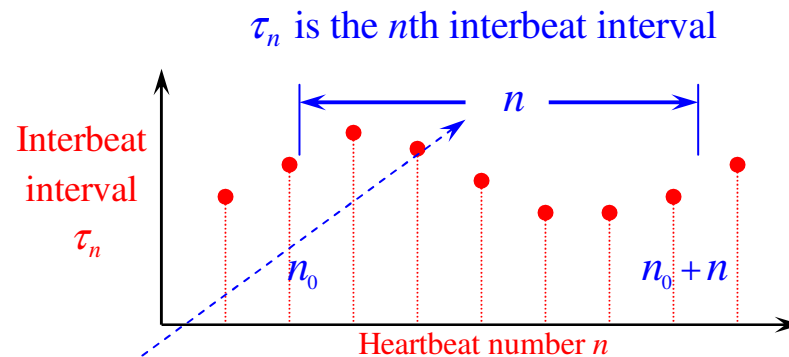
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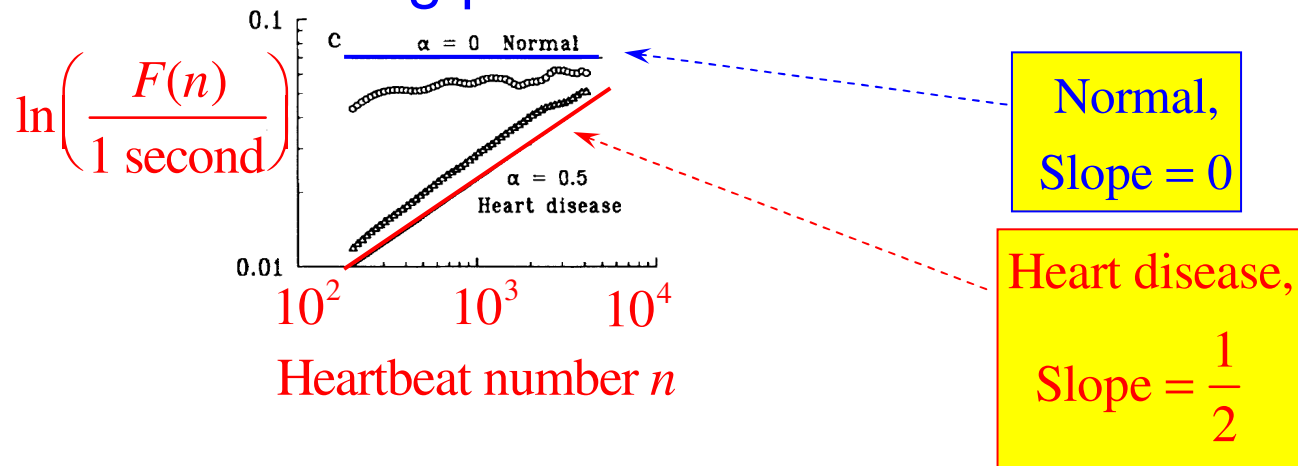
1. Introduction

□ Heartbeat time series $\{\tau_n, n = 1, 2, \dots, N\}$



Large time intervals $n : 10^4$ beats ($t : 10^4$ seconds : hours) are what matter

□ Different scaling patterns in health and disease

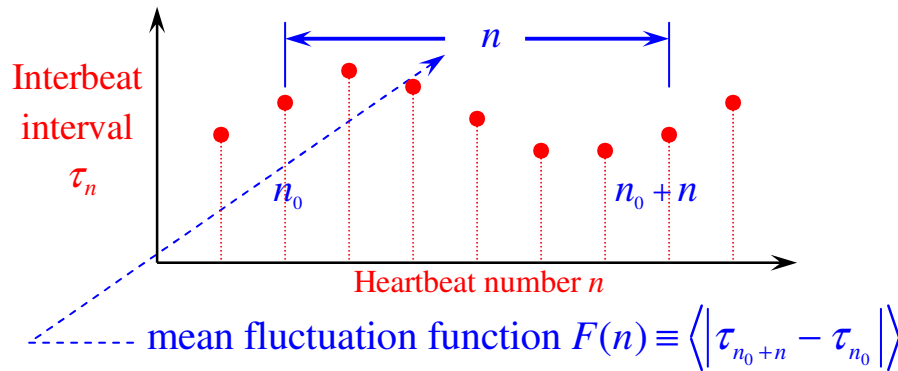


2. Long-Range Anticorrelations and Non-Gaussian Behavior of the Heartbeat

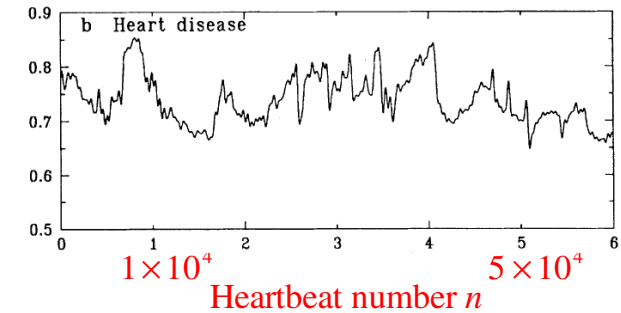
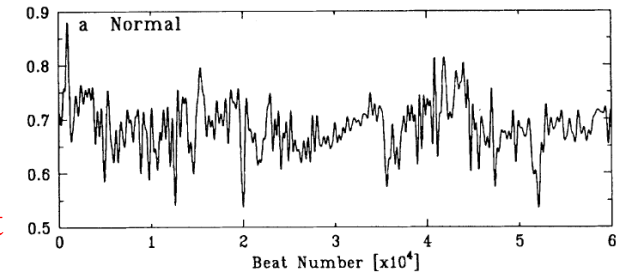
Peng et al.,
Phys Rev. Lett. **70**, 1343 (1993)

Heartbeat time series $\{\tau_n, n=1,2,\dots,L\}$

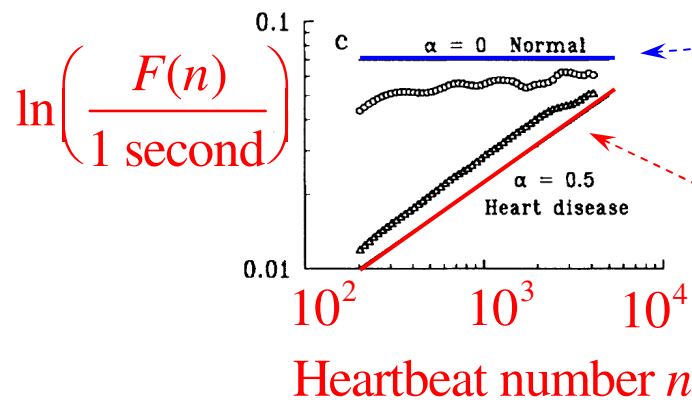
τ_n is the n th interbeat interval



Interbeat interval τ_n (s)



Different scaling patterns in health and disease



Normal,
Slope = 0

Heart disease,
Slope = $\frac{1}{2}$

Like the magnitude of the distance traveled in, e.g. a random walk of n steps
For a random walk,
 $r : \sqrt{Dt}$, Slope = $\frac{1}{2}$

3. Scaling and Self Similarity

□ Magnifying a picture

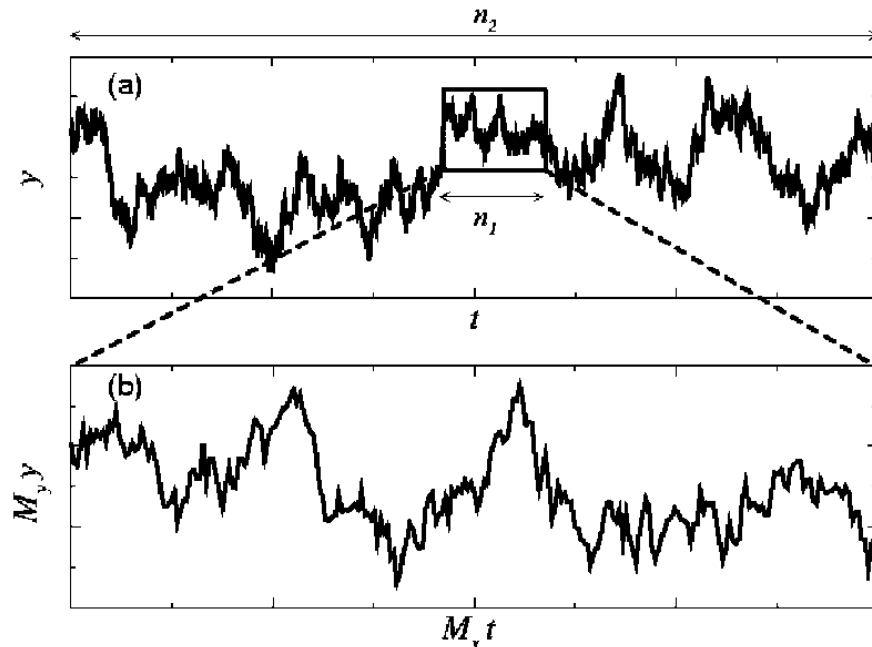
Magnification factors

$$M_{\text{vertical}}, M_{\text{horizontal}}$$

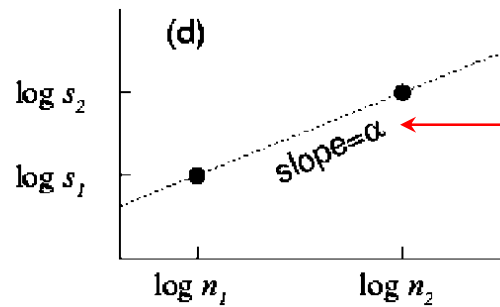
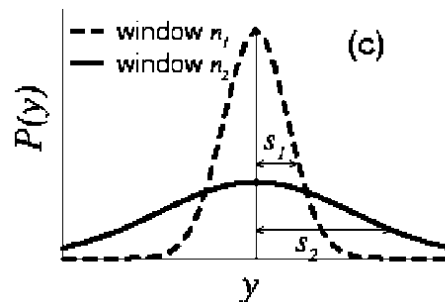
Scaling relation

$$M_{\text{vertical}} = (M_{\text{horizontal}})^\alpha$$

Self-Similarity of a Time Series



□ Rescaling the probability distribution



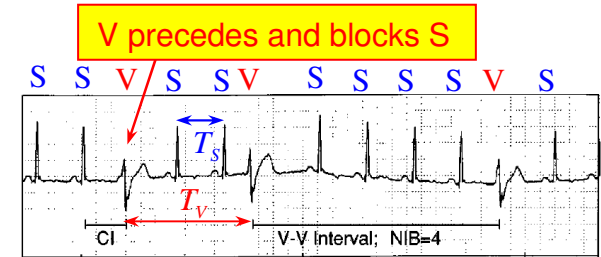
$$\log M_{\text{vertical}} = \alpha \log M_{\text{horizontal}}$$

4. Complex Patterns of Abnormal Heartbeats

Ventricular beat mechanisms

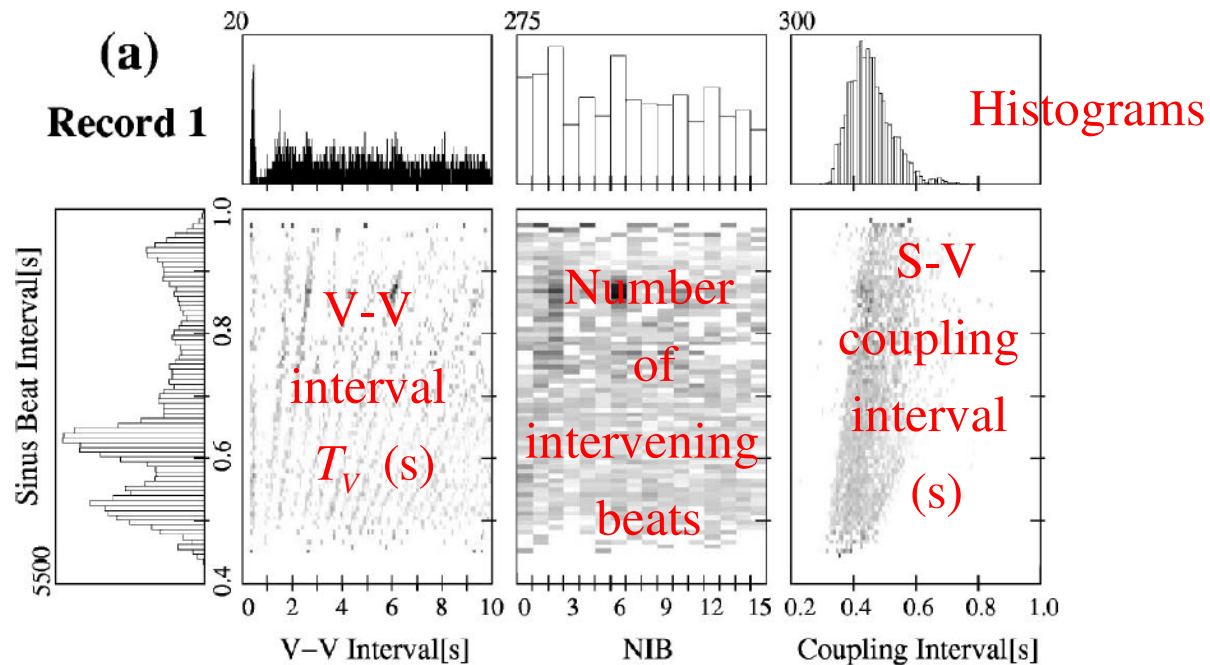
- Reentry
- Triggered activity (S-V nerve crosstalk)
- Independent spontaneous pacemaker for ventricular beats

Schulte-Frohlinde et al.,
Phys Rev. E **66**, 031901 (2002)



Heartprints

Sinus
beat
interval
 T_s (s)



5. Summary

- ❑ We have described a statistical data analysis method called detrended fluctuation analysis that has been developed by collaboration of cardiologists, physicists, and others.
- ❑ This was done using the high-level programming language Mathematica that allows easy graphical presentation of intermediate results.
- ❑ Copies of the notebooks and files that you have been working with may be taken now and will be available on the web site.

5. References

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17. Mathematica Player can be downloaded for free at: <http://www.wolfram.com/products/player/>