Normalising in stability analysis; why (not?)

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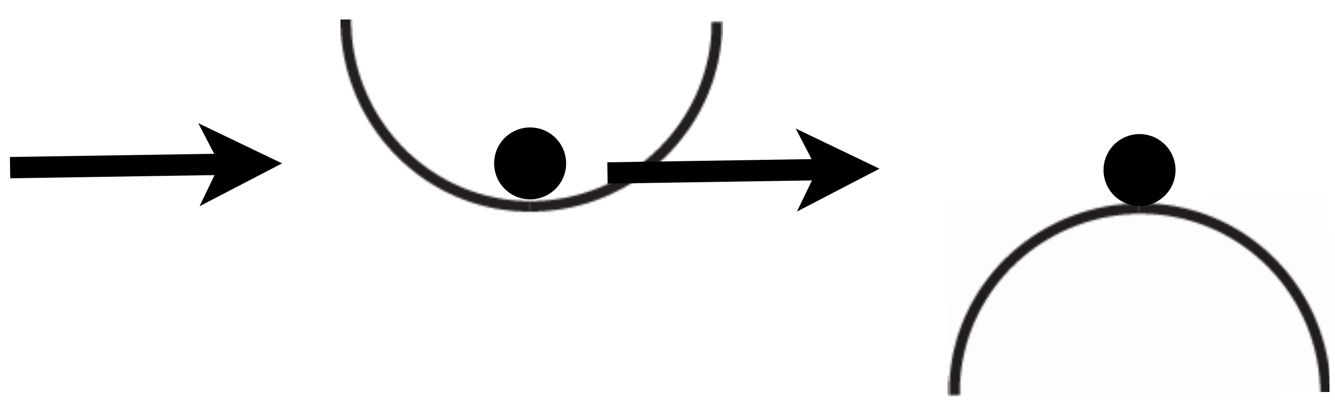
- Effects of time series length
- Effect of normalising time
- Effects of calculating log(div)/s vs. log(div)/stride

Recap: Local divergence exponents

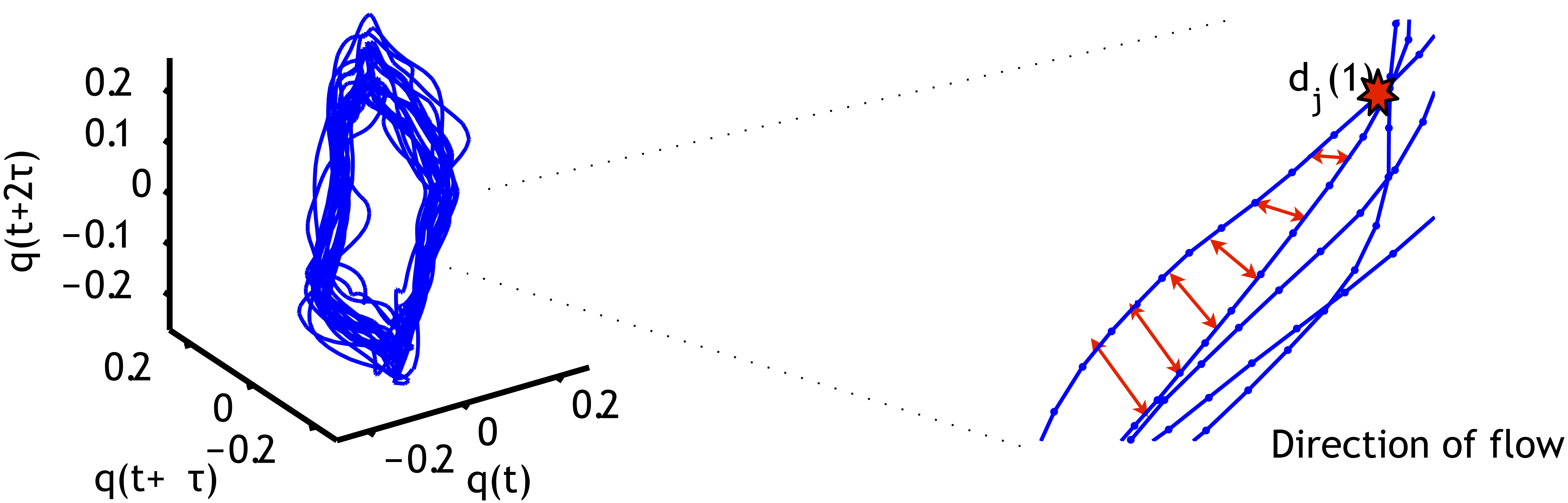
Which one is (more) stable?



Recap: Local divergence exponents

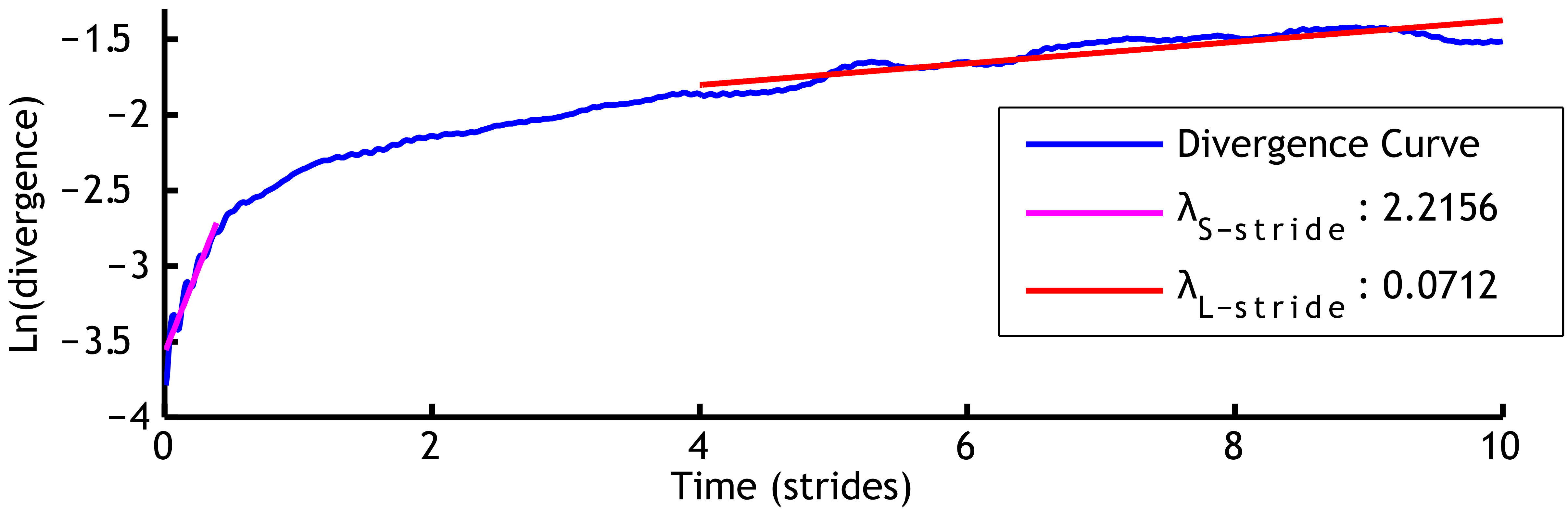
- the small variations in gait can of course be regarded as small perturbations
- in which case it would be interesting to see what happens to these small perturbations over time
- this is exactly what maximum Lyapunov exponents do

Recap: Local divergence exponents

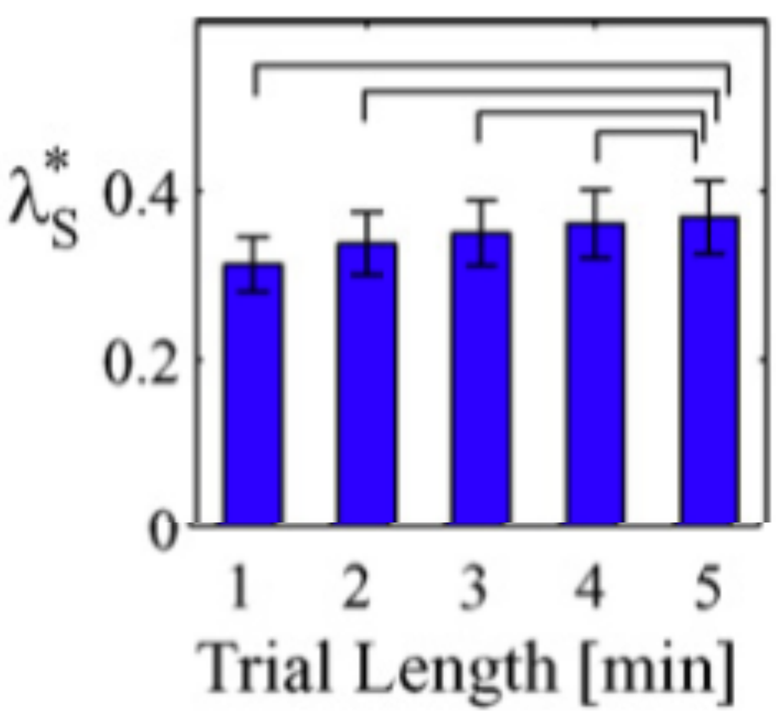


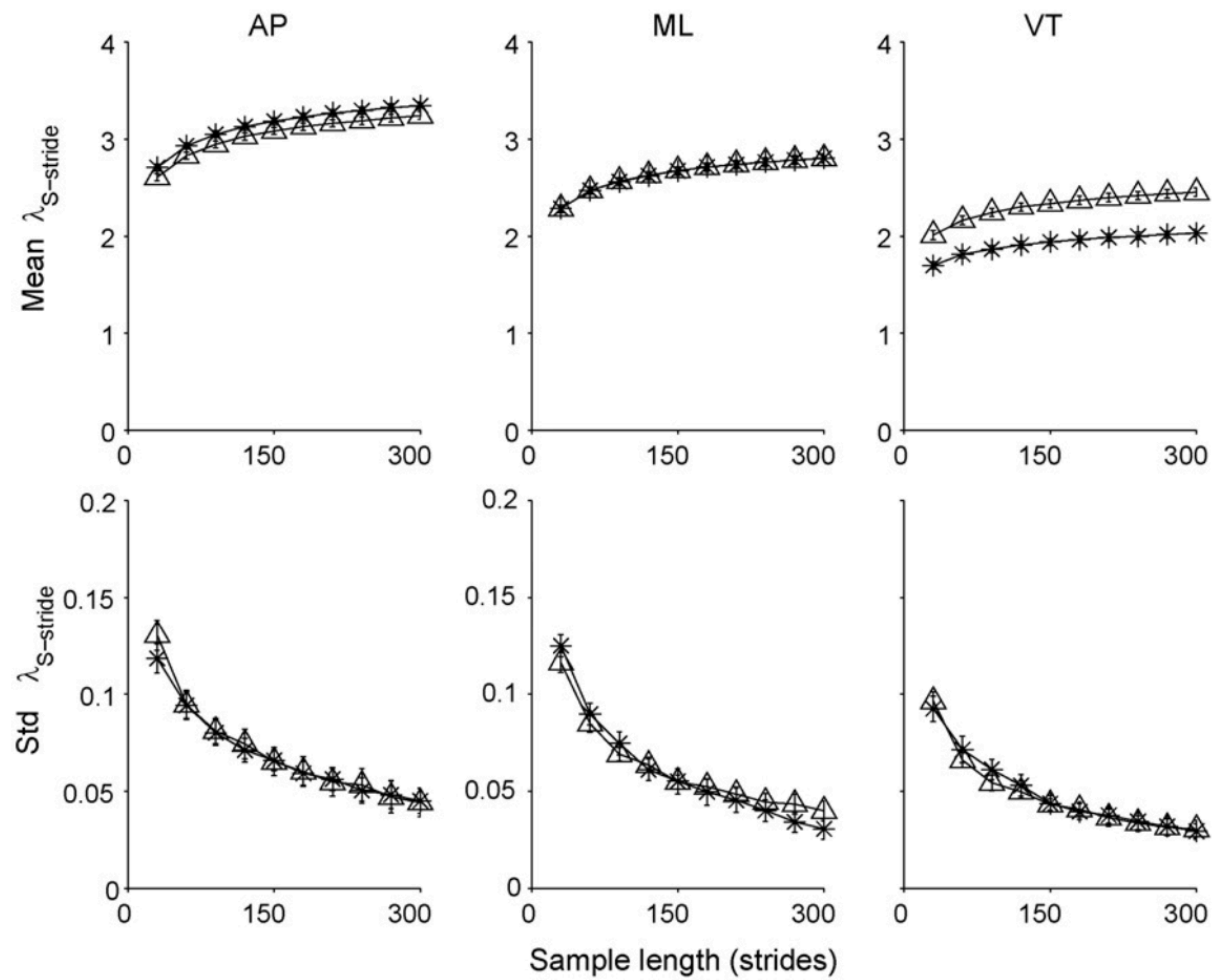
Rosenstein et al 1993; Dingwell et al 2000

Recap: Local divergence exponents



Effects of time series length

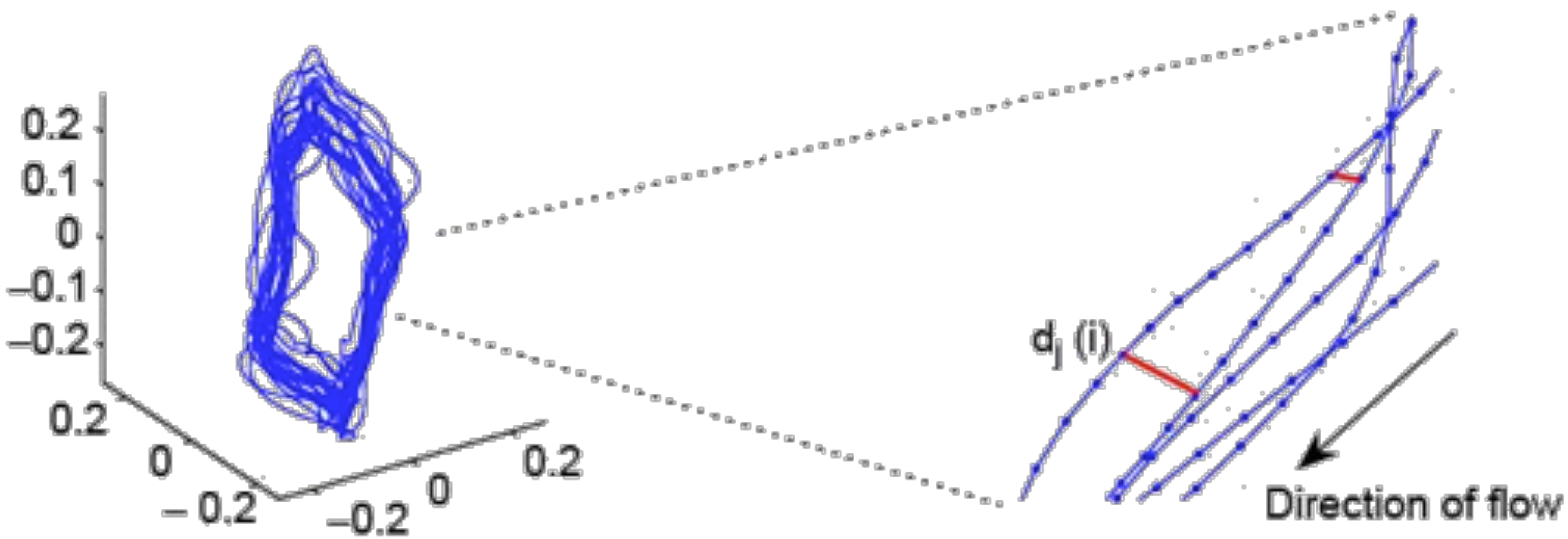




Kang et al 2006;Bruijn et al 2010

But why?

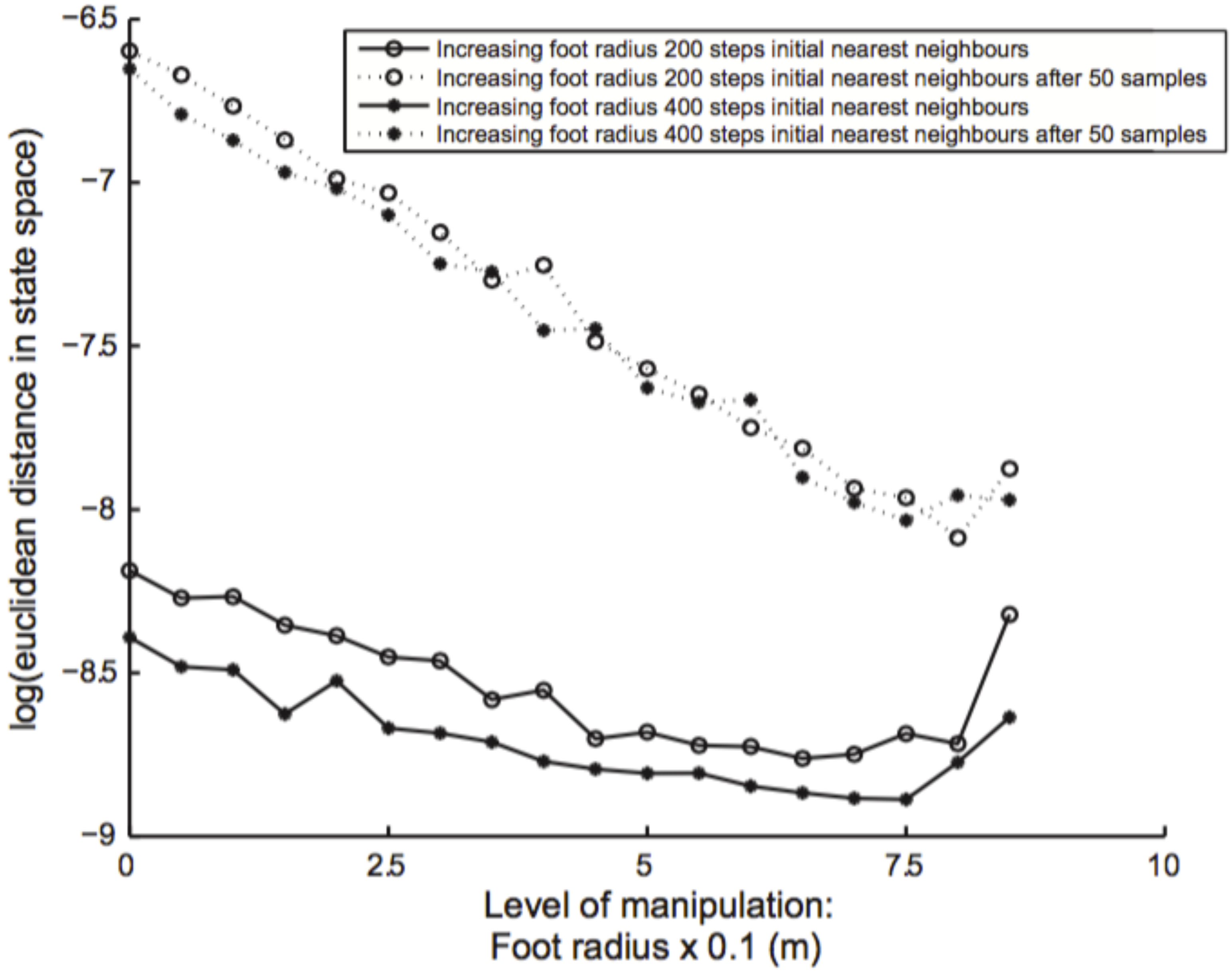
- I have proposed that this could simply be due to an increase in nearest neighbours, increasing the chance that they get closer



Is that really all there is to it?

- long range correlations have been reported in human gait, could these also cause it?
- could yes, but I don’t think they do (see later when talking about normalisations)

Is that really all there is to it?



Bruijn et al 2012

Solutions

- choosing nearest neighbours carefully:

For each point $\mathbf{x}_i$, consider the shell between two spheres centered at $\mathbf{x}_i$ of radii $r_{\min} < r$, and consider the set of trajectory points $\mathbf{x}_j$ within this ith shell:

$$r_{\min} \leq ||\mathbf{x}_j - \mathbf{x}_i|| = \left[\sum_{l=0}^{k-1} (x_{j+lm} - x_{i+lm})^2 \right]^{1/2} \leq r \, .$$

The use of a shell, rather than a ball, is to minimize the effects of noise or measurement error, since these effects are greatest when $||\mathbf{x}_j - \mathbf{x}_i||$ is small. After a time $n\Delta t$,

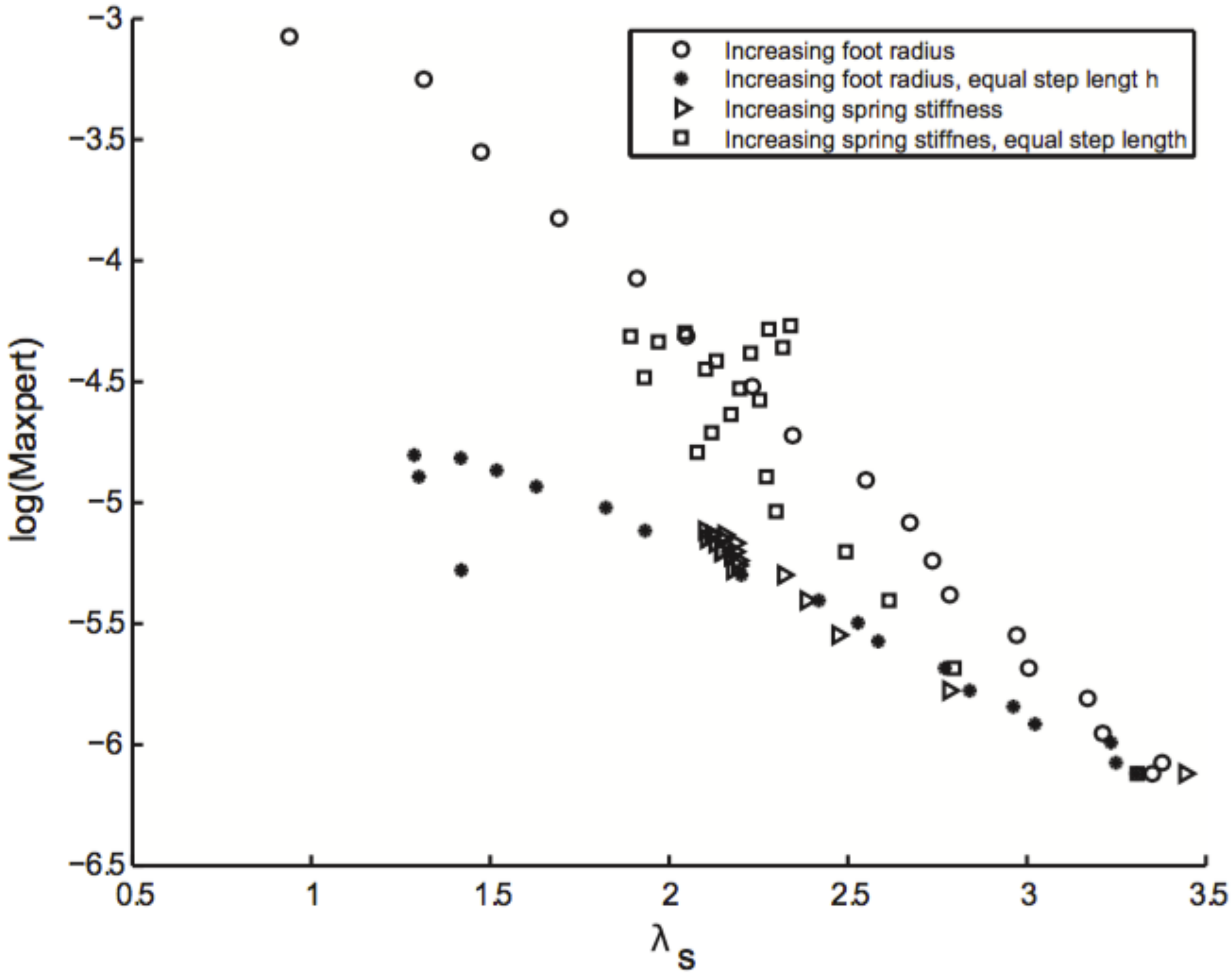
- but how to determine rmin and r?

Zeng et al 1991

Solutions

- using equal amount of cycles
- is our usual choice
- and works quite well

Results model

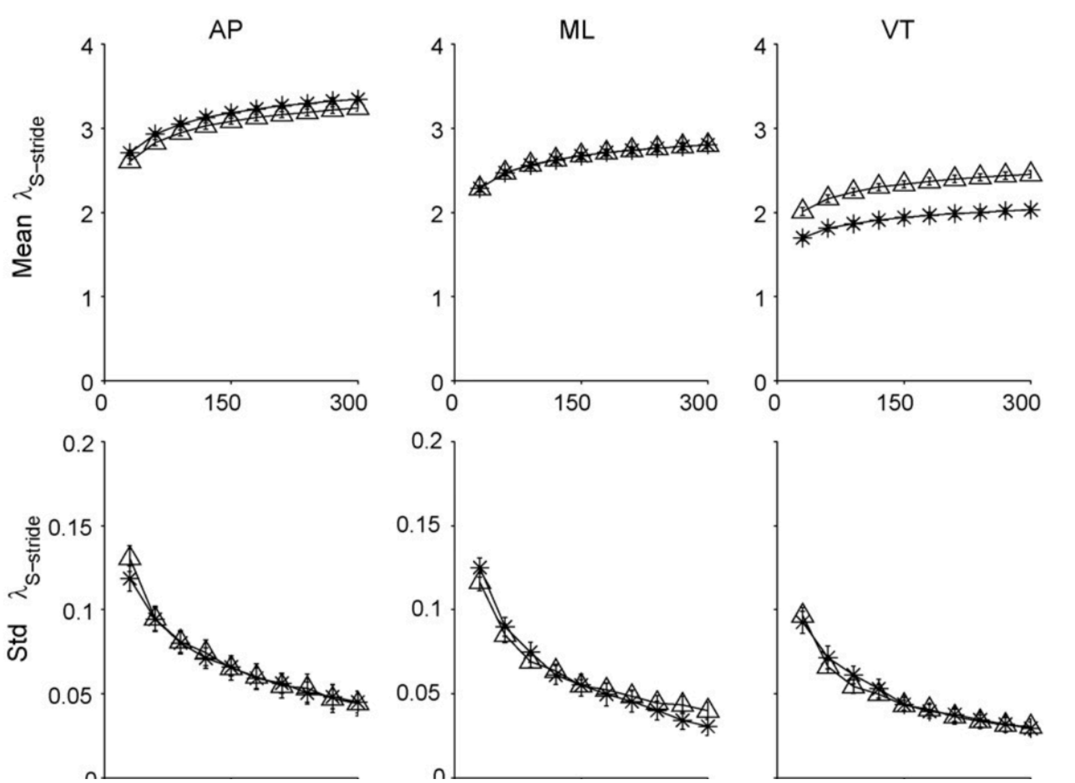


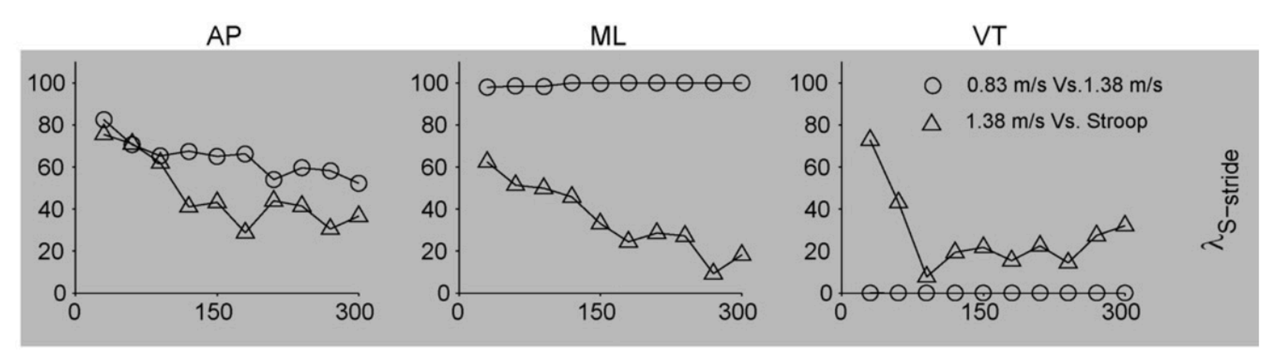
Bruijn et al 2012

So how long should your data series be?

- Of course, ideally as long as possible. But if you get fatigue, this also doesn't help you.

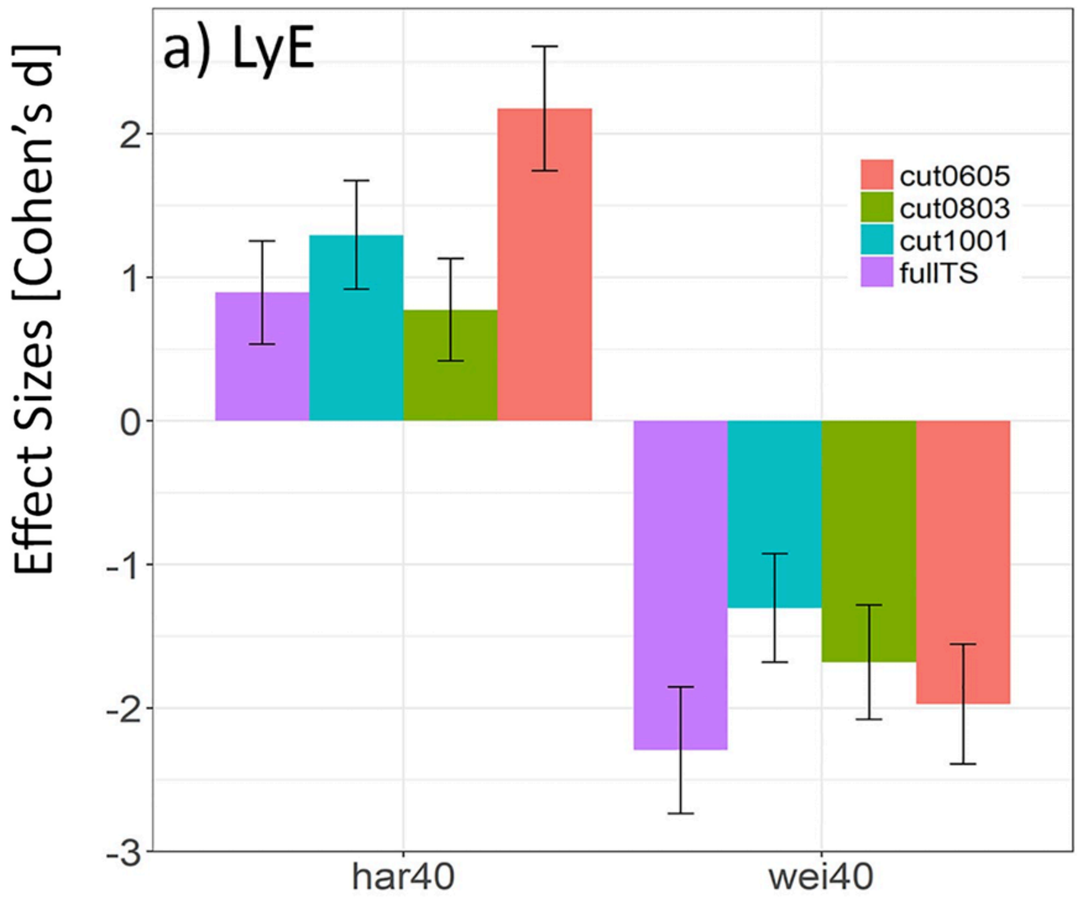
- We have (somewhat arbitrarily) suggested 150 strides





What if you have short time series?

- You can ‘stitch’ time series together!
- Or averaging over short time series also works!



Orter et al 2019

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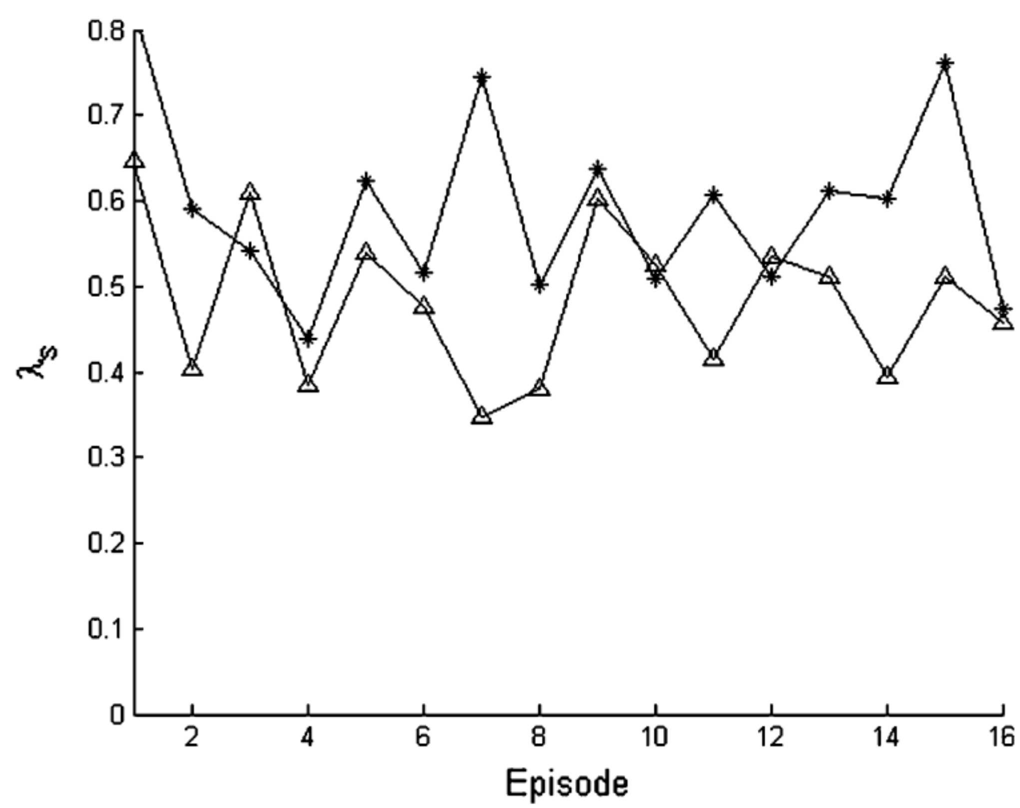
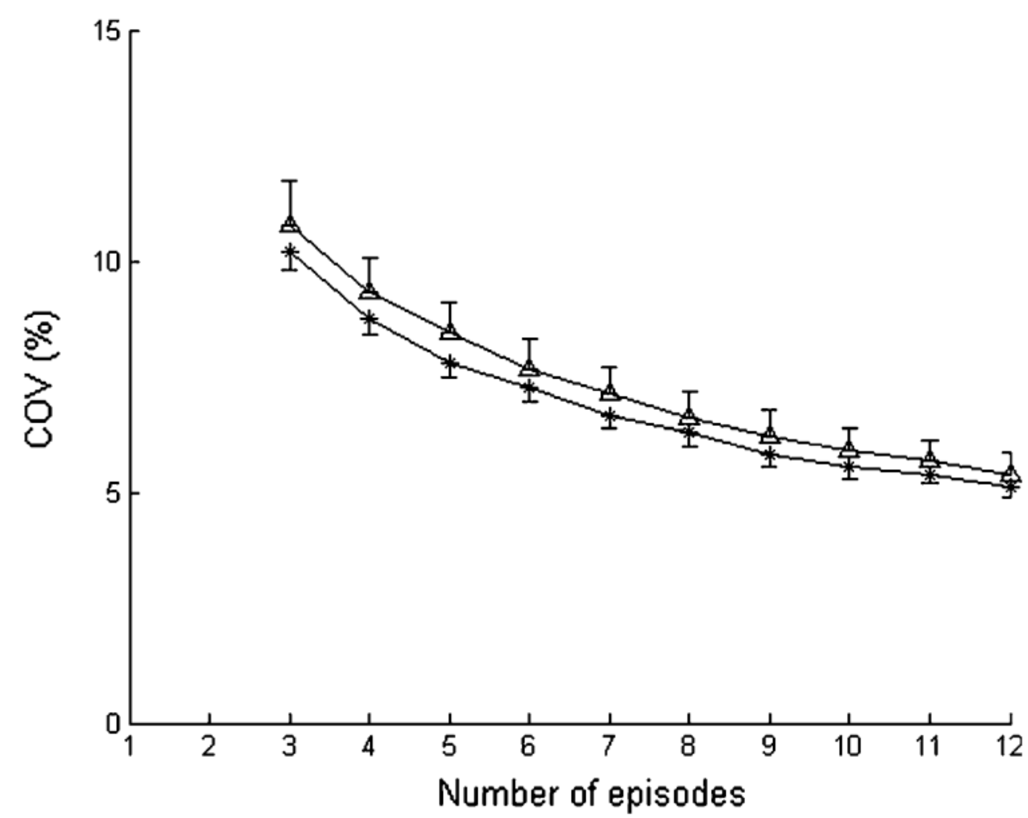




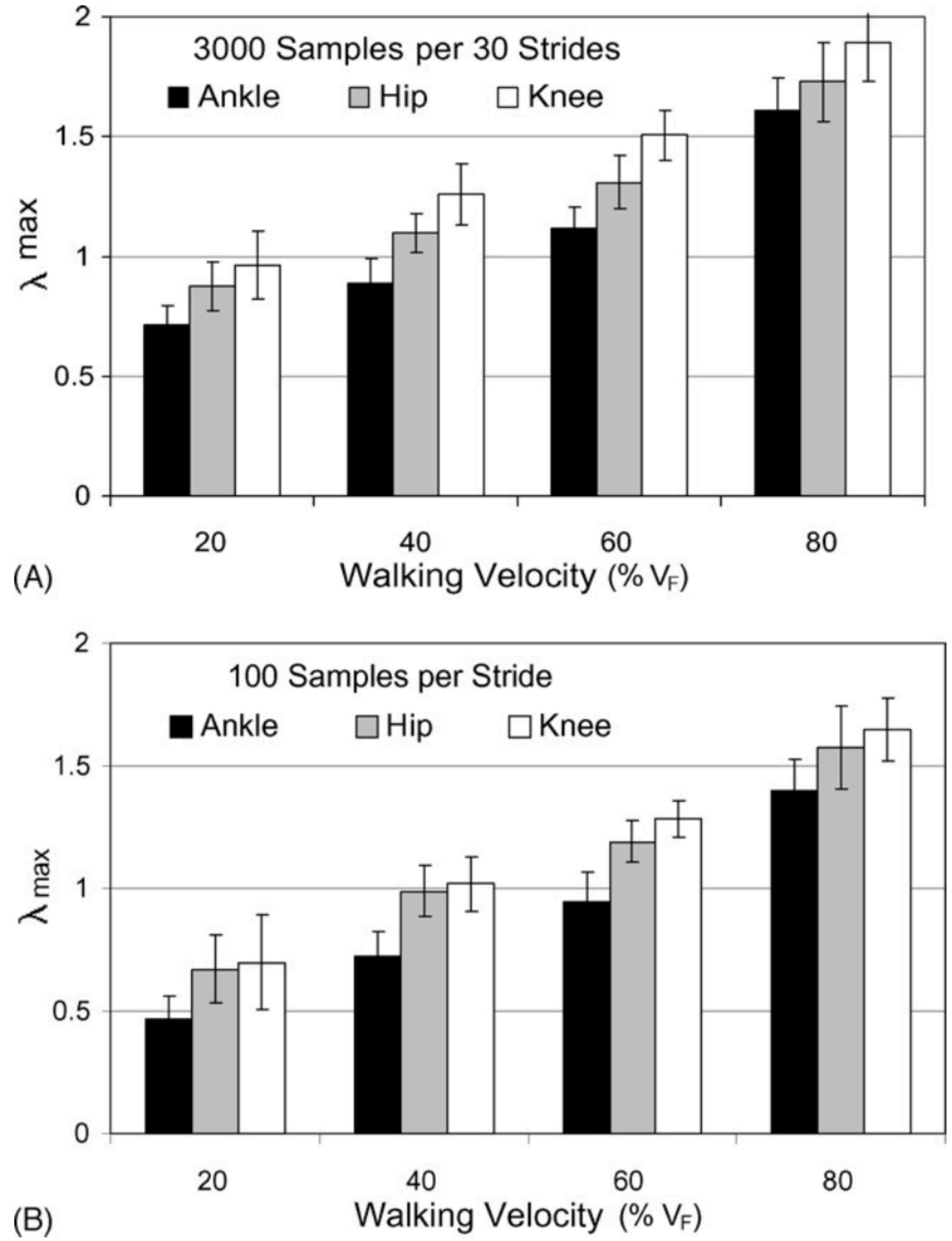
Sloot et al. 2011

Effect of normalising time

- why time normalise keeping temporal variability? (Vs. not normalising, or time normalising each cycle)
  - simplifies analysis; in theory, delay should be more or less equal (same main frequency content, i.e. stride time)
  - differences between normalisations seem minor
  - ut may affect estimates of long term slope (whatever that may mean)
  - allows checking if state space is correct

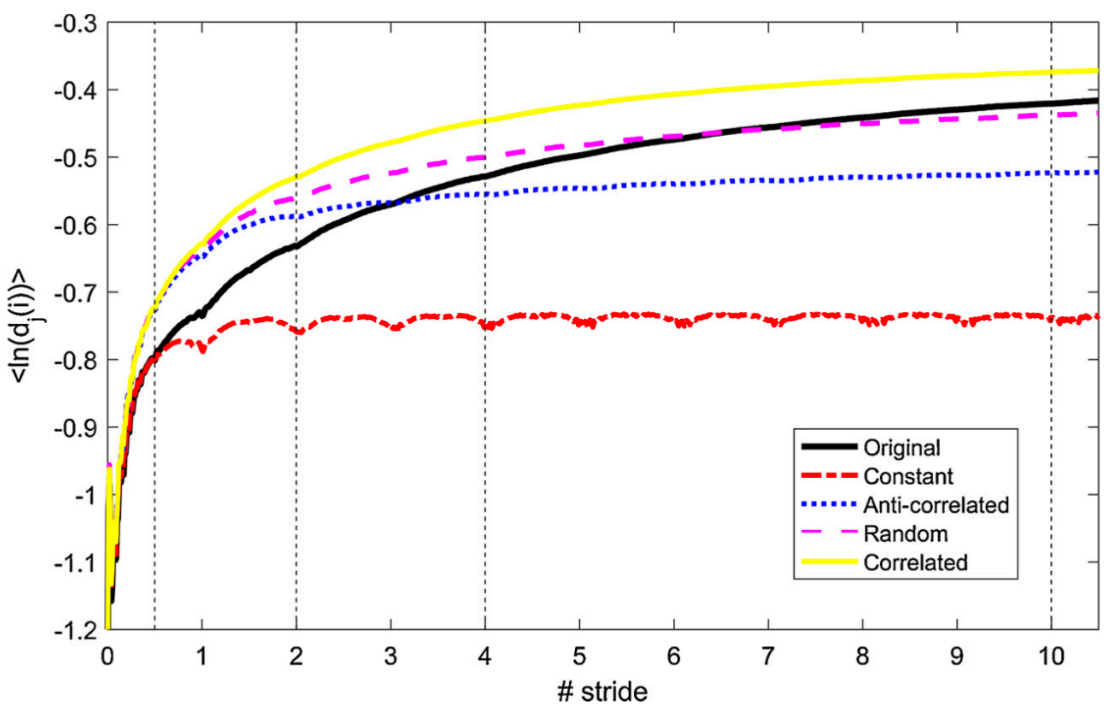
Raffalt et al 2019;Stenum et al 2014

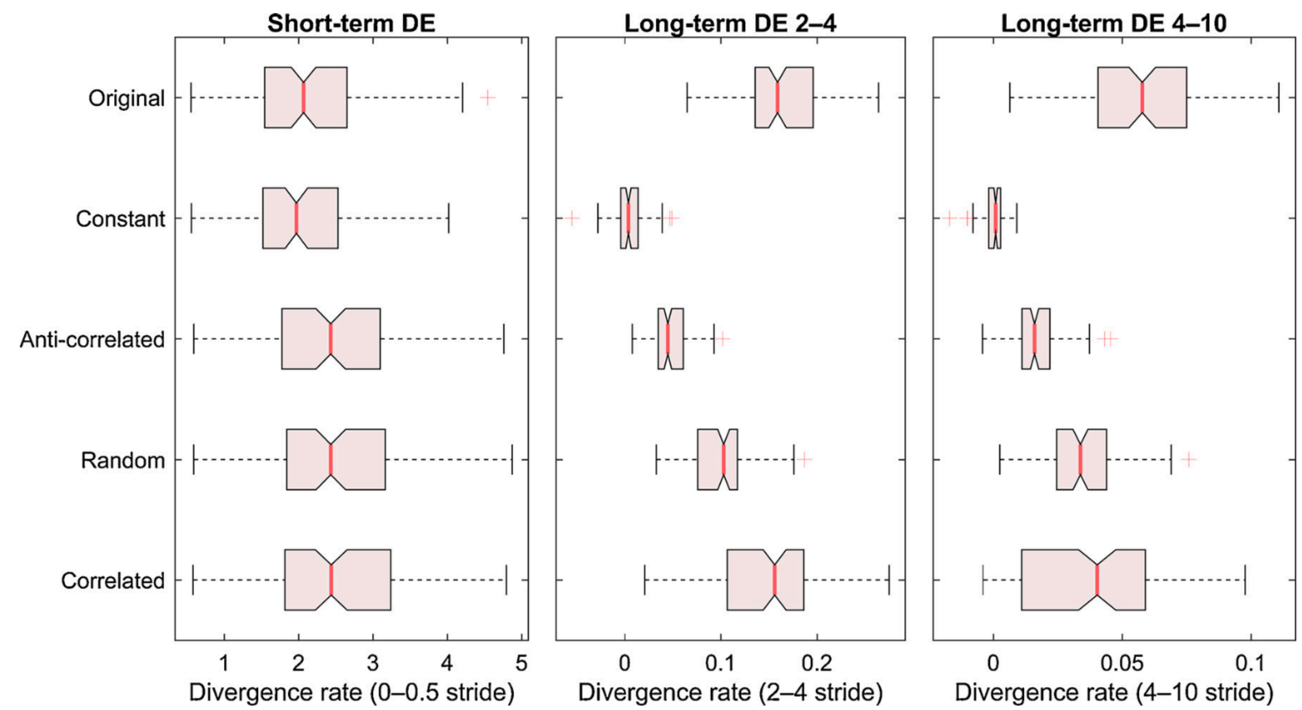
Differences between normalisations seem minor



England & Granata (2007)

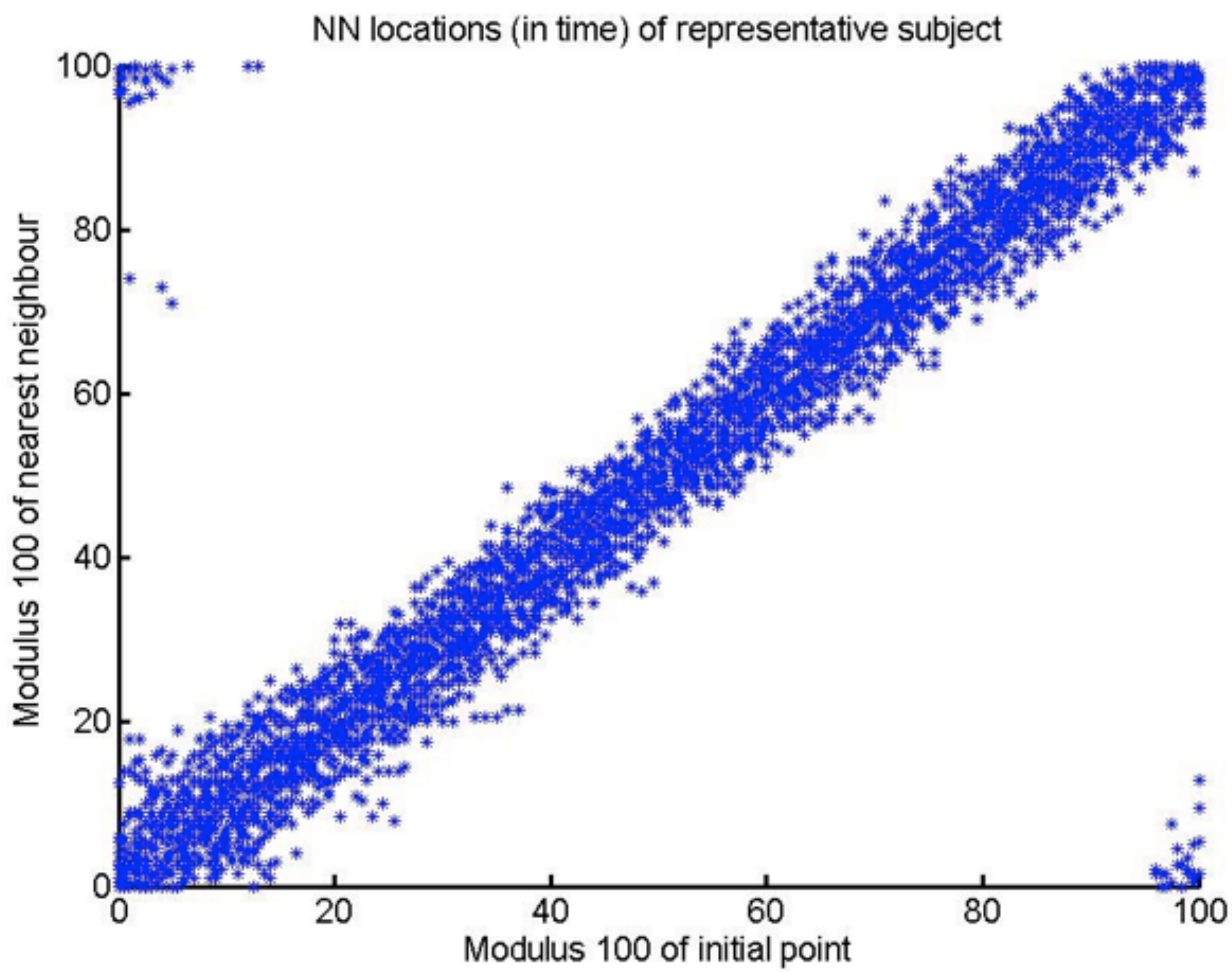
But may affect estimates of long term slope





Terrier & Reynard (2018)

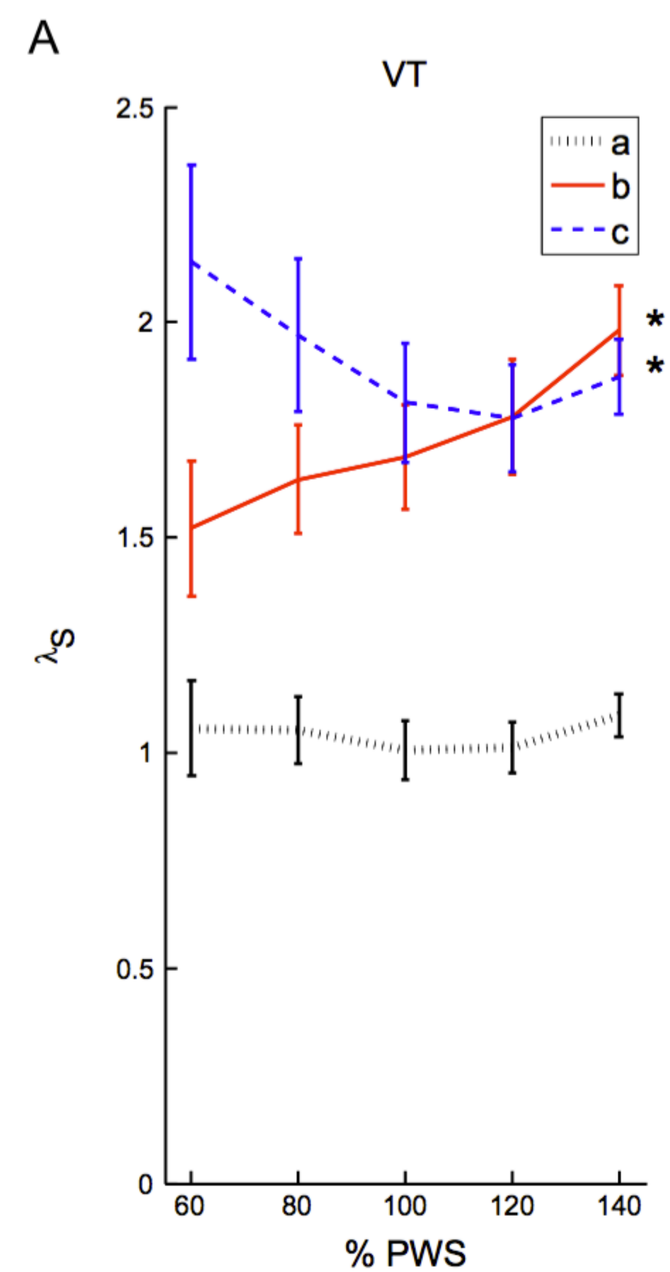
Normalisation allows checking if state space is correct



Unpublished analysis

Effects of calculating log(div)/s vs. log(div)/stride

- usually lambda calculated as div/stride
- **A**: 3 min data for each speed
  (more strides per speed!)
  div/stride
- **B**: 115 strides for each speed
  div/second (artificial increase with speed?)
- **C**: 115 strides for each speed
  div/stride



Stenum et al 2014

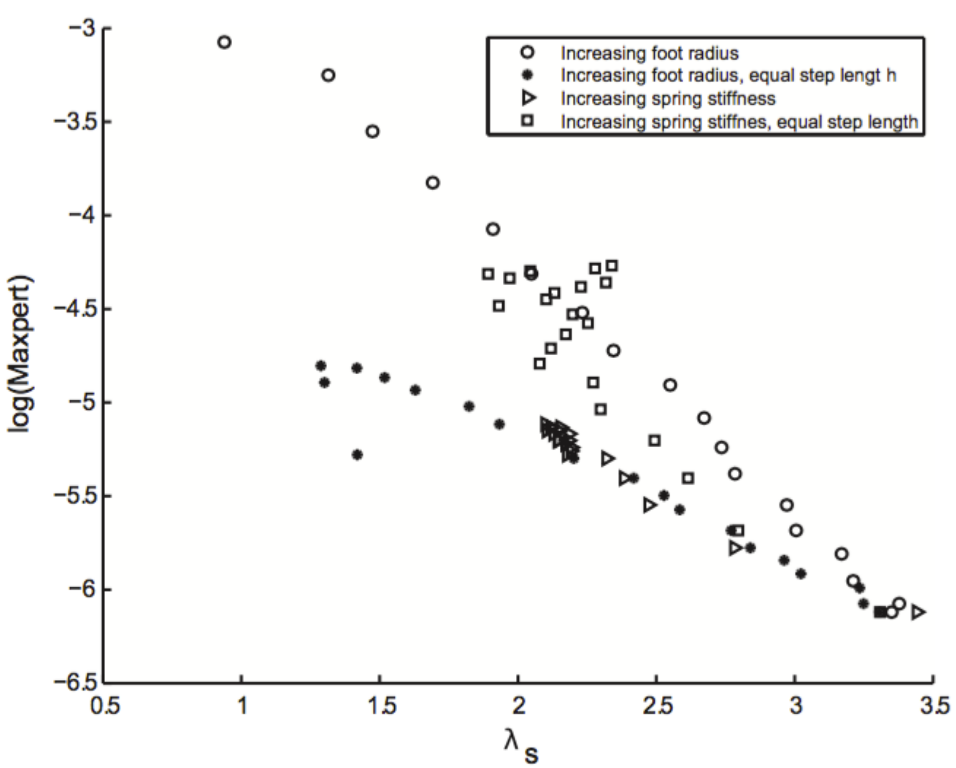
Per stride (vs. Per second)

- Gait happens in steps
- It doesn’t matter that much how much you diverge in time, what matters more is how much you diverge per step; that shouldn’t be too much

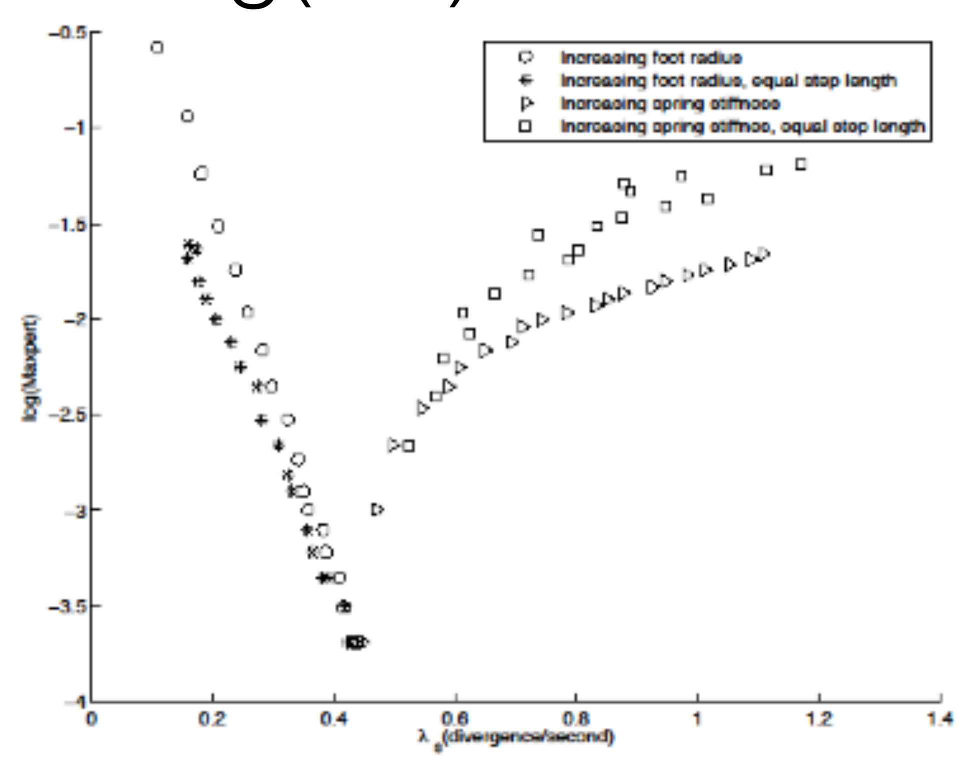
Per stride (vs. Per second)

- but of course, we do not know which one is right….
- so let’s turn to our model

log(div)/stride



log(div)/second



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Conclusions

- Use equal amounts of strides
- Normalise to a standard time (while keeping between stride variations in stride time intact)
- Express local divergence exponents as log(div)/stride