Daily Mobility Patterns in Power Wheelchair Users:

What complexity measures can be used to describe mobility patterns?

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Introduction

- Technology improvements
  - Wireless technologies
  - Increased memory
  - Low power consumption and longer battery lives
- Data collection with increased sampling rates and increased time period
- More robust, commercial products available for activity monitoring (pedometers, accelerometer based activity monitors, wheelchair odometers, etc)
- Research environment shifting from lab to community
- New Questions
  - How much data is good enough?
  - How do we analyze all of this data?

Why measure “mobility” in the community?

- Assessing outcomes of medical interventions designed to optimize mobility or physical activity
  - Laboratory and controlled environments do not reflect the complex environments people need to navigate
  - Improved gait doesn’t necessarily mean improved mobility!

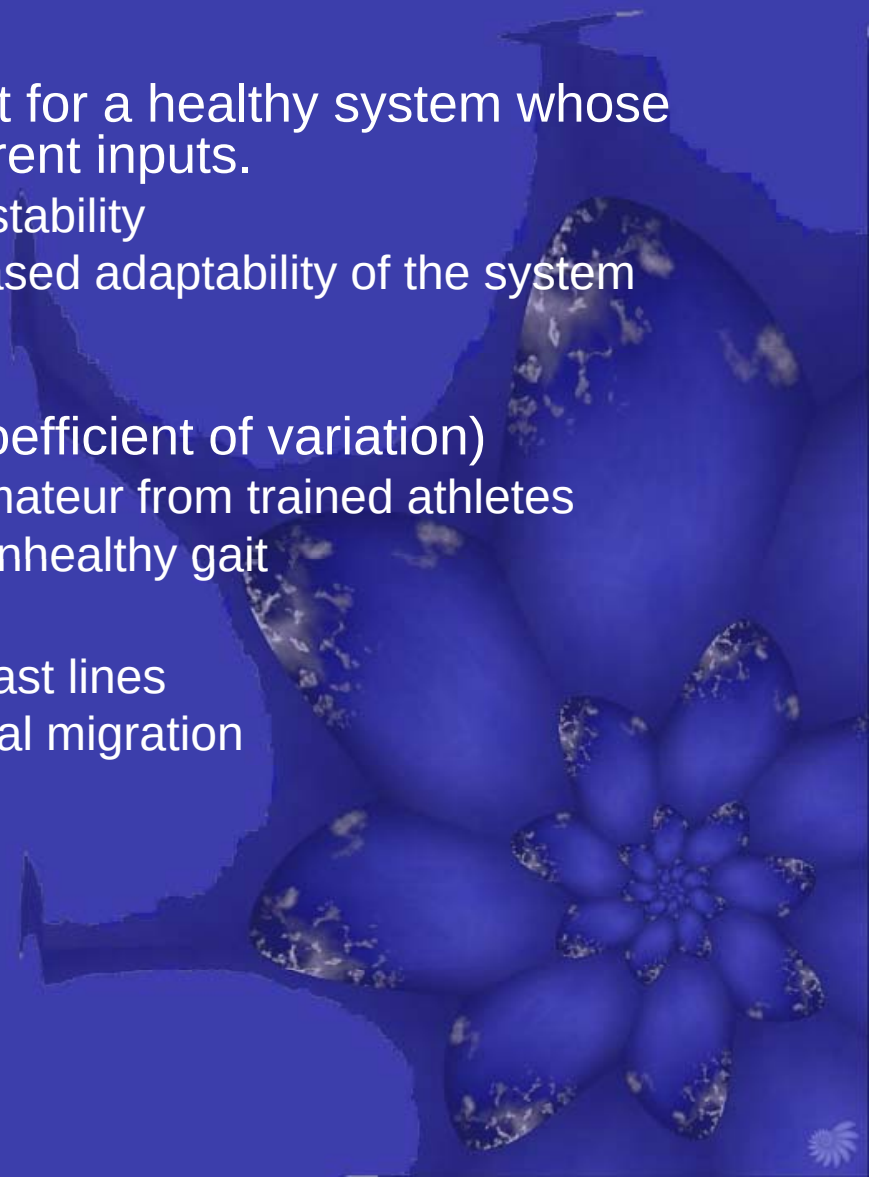
Complexity Background

Some amount of complexity is important for a healthy system whose behavior is modulated by many different inputs.

- Too much complexity may lead to instability
- Too little complexity implies a decreased adaptability of the system

Different Measures of Complexity

- Variability (standard deviation and coefficient of variation)
  - Increased variability distinguishes amateur from trained athletes
  - Decreased variability distinguishes unhealthy gait
- Fractals: scalable self-similarity
  - Common in nature: trees, clouds, coast lines
  - Biology: termite tunneling and narwhal migration
  - Physiology: heart beat, gait
- Entropy



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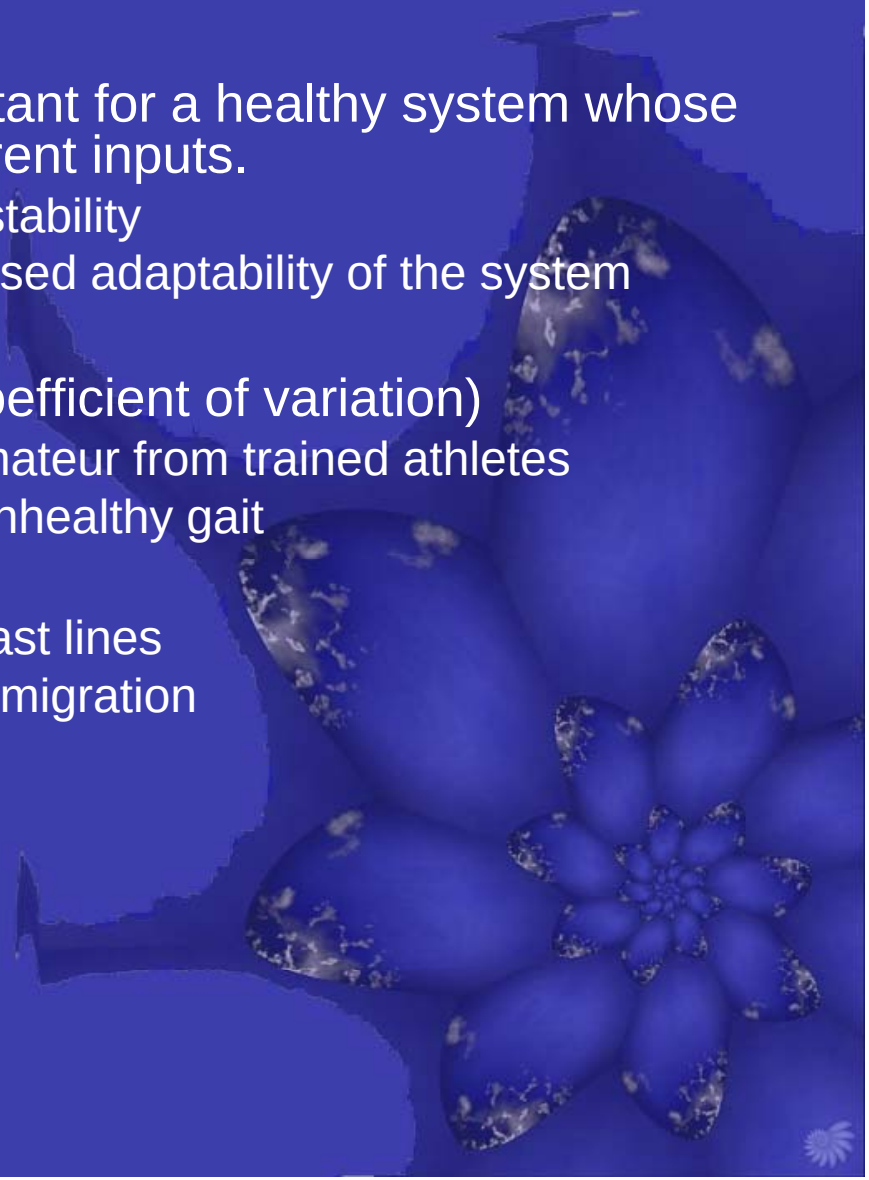

Complexity Background: Entropy

- Measure of uncertainty or variability
  - Thermodynamics
  - Information Theory
  - Physiology
- Approximate Entropy (ApEn: Pincus, 1991)
  - Describes the predictability or regularity of a time series
  - “Measures the logarithmic probability that a series of data points a certain distance apart will exhibit similar relative characteristics on the next incremental comparison”

Complexity Background: Entropy

- ApEn(m,r)
- m = embedded dimension, number of consecutive components to compare, m=2
- r = similarity threshold, r = 0.2*stdev
- Low entropy (near 0) = highly periodic, predictable
- High entropy (near 2) = unpredictable, random

Examples of Entropy in Physiology

- Growth hormone secretion:
  - Increased entropy for subjects with tumors
- Heart rate
  - Decreasing entropy for 2 hours prior to atrial fibrillation
- Gait
  - Children with Down syndrome have increased entropy in segmental angular displacements compared to children with typical development

Research Questions

- Does daily mobility show complex patterns similar to those shown in simple gait?
- Can ApEn be used to compare the complexity of mobility between subjects?
- Can ApEn be used to compare the complexity of mobility of a single subject before and after an intervention?
- What is the appropriate way to apply the ApEn analysis?
  - Best sampling rate or *epoch* of the data

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Study Population:

Going from an upright wheelchair to a Tilt-in-Space wheelchair

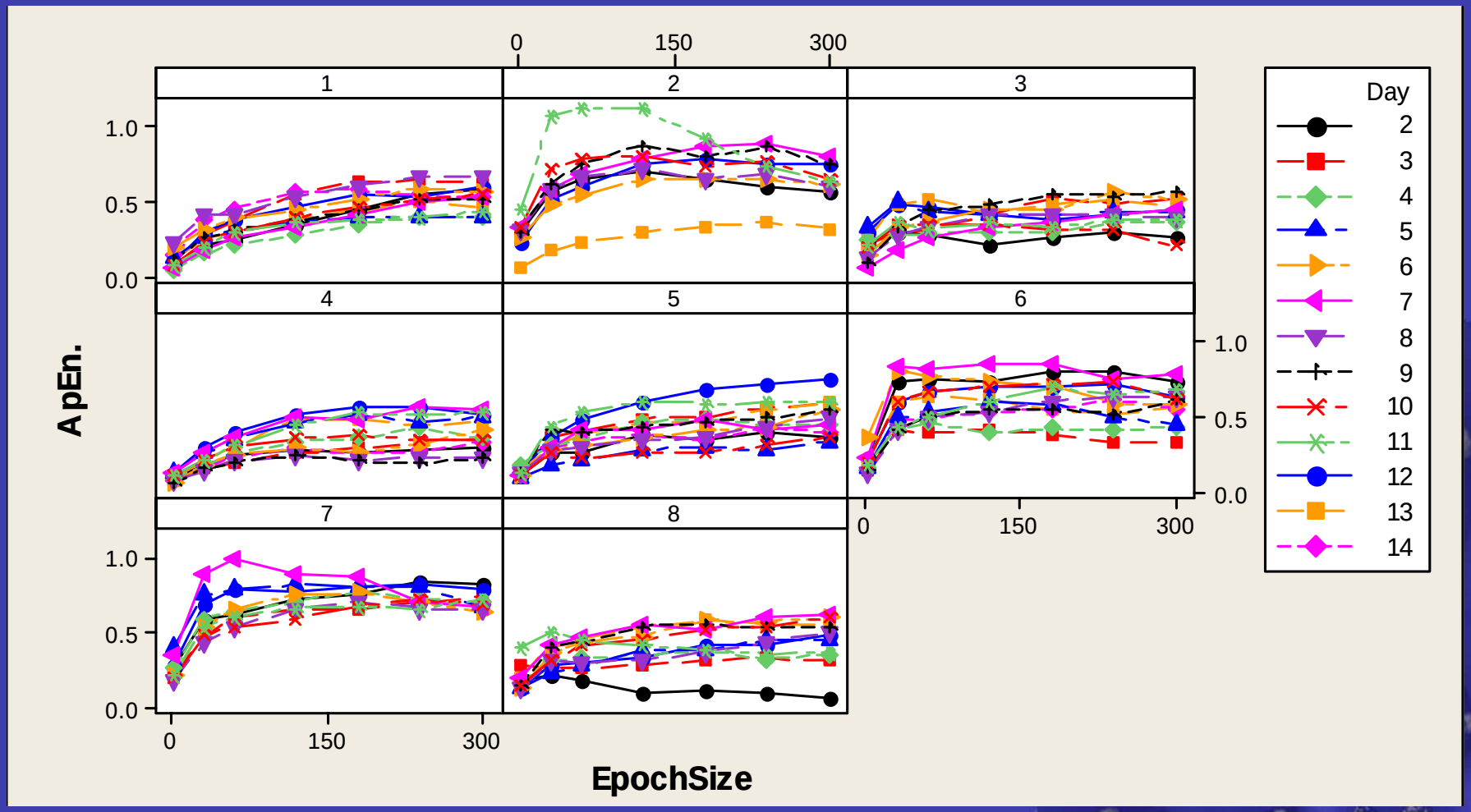
Overview of the Power Wheelchair Study

- Subjects
  - Currently using a power upright wheelchair
  - Prescribed a power tilt-in-space wheelchair
  - Any disability, so far subjects have had: MS, SCI, MD
- Instrument with occupancy sensor, wheel odometer, and position sensor
  - 2 weeks before acquisition of new chair
  - 2 weeks 3 months after arrival of new chair
- Collect number of wheel revolutions every 2 seconds (similar to counting number of steps)

Expectations Based on Epoch Size

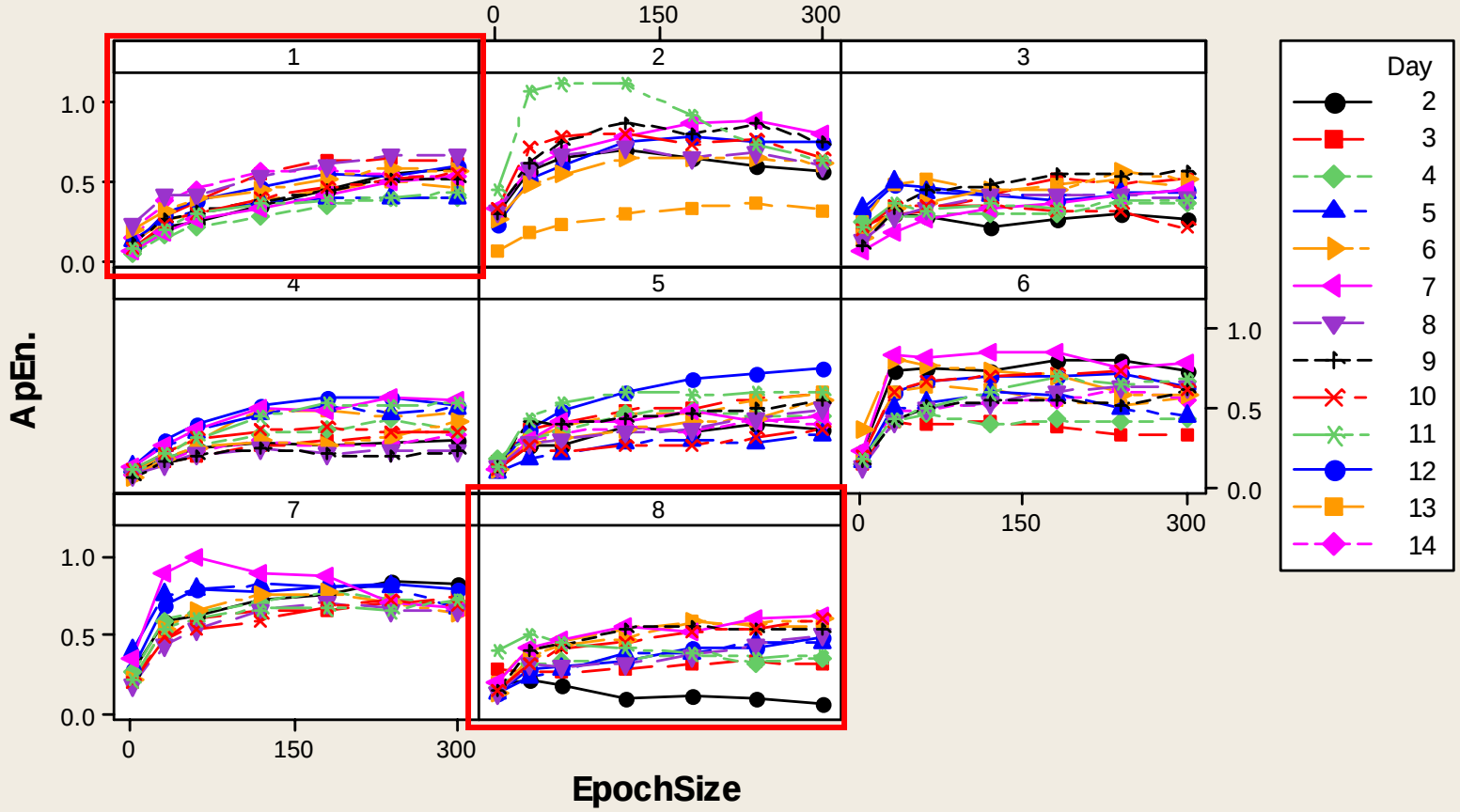
- With **increased epoch size**,
  - more averaging of data
  - **entropy should decrease**
- With **decreasing epoch size,**
  - more zero-count epochs which are inherently predictable,
  - **entropy should decrease**

- Which effect dominates ApEn analysis?
- Is ApEn too sensitive to Epoch size to use for analysis?



For most subjects, ApEn INCREASES with increasing epoch size…

- Influence of zero-count epochs dominates
- Increases with different slopes for different subjects
- Some subjects and days do NOT increase



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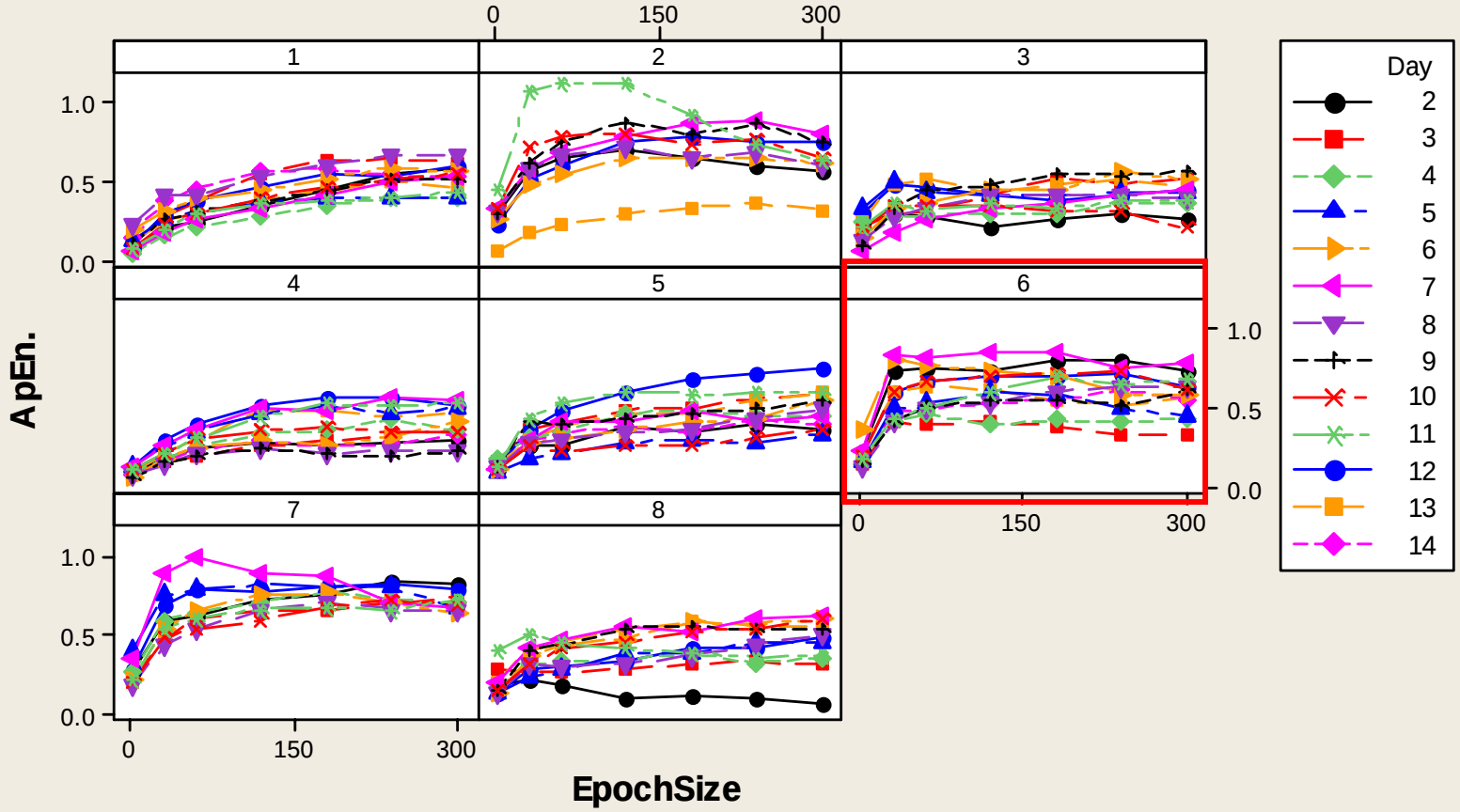

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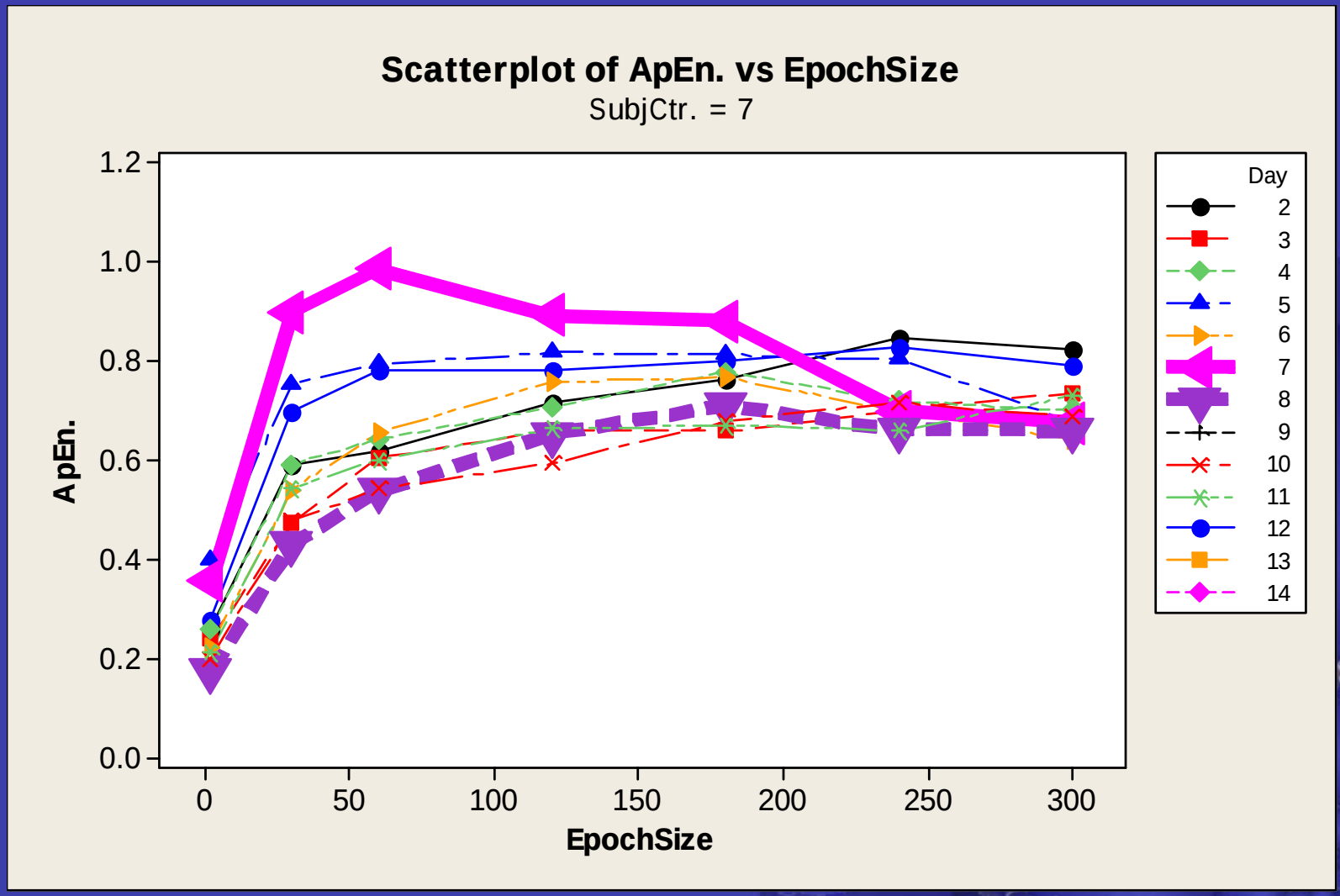
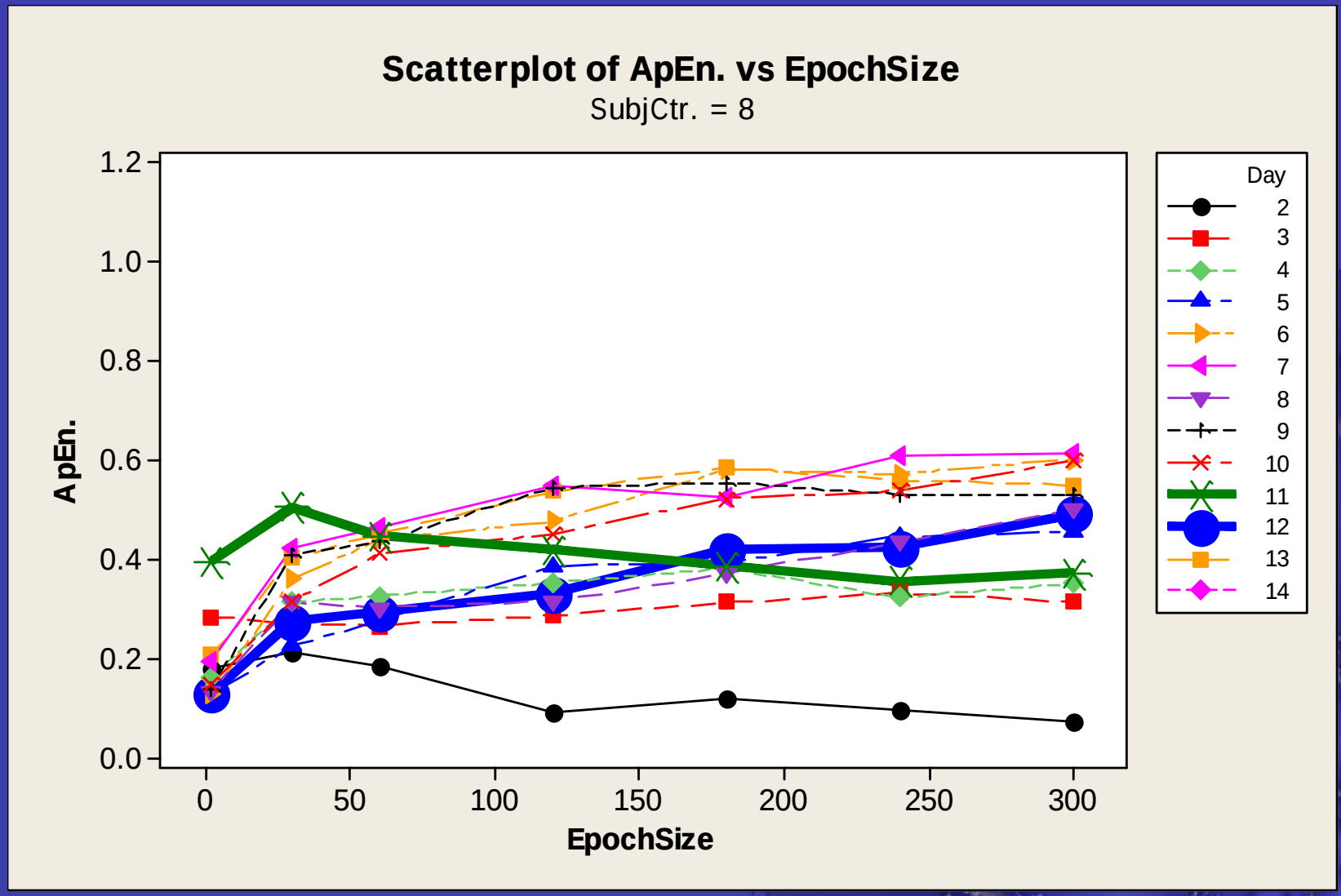
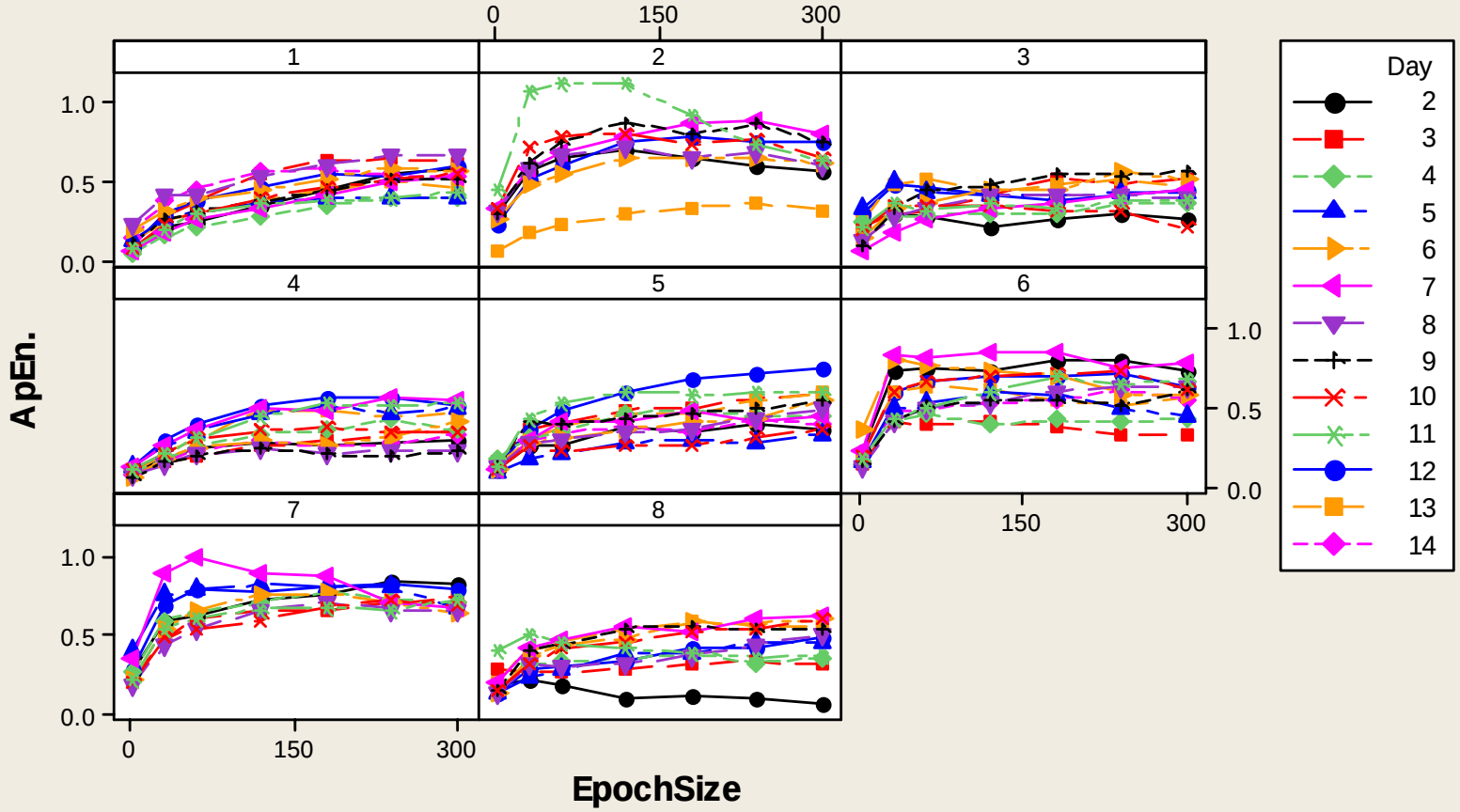


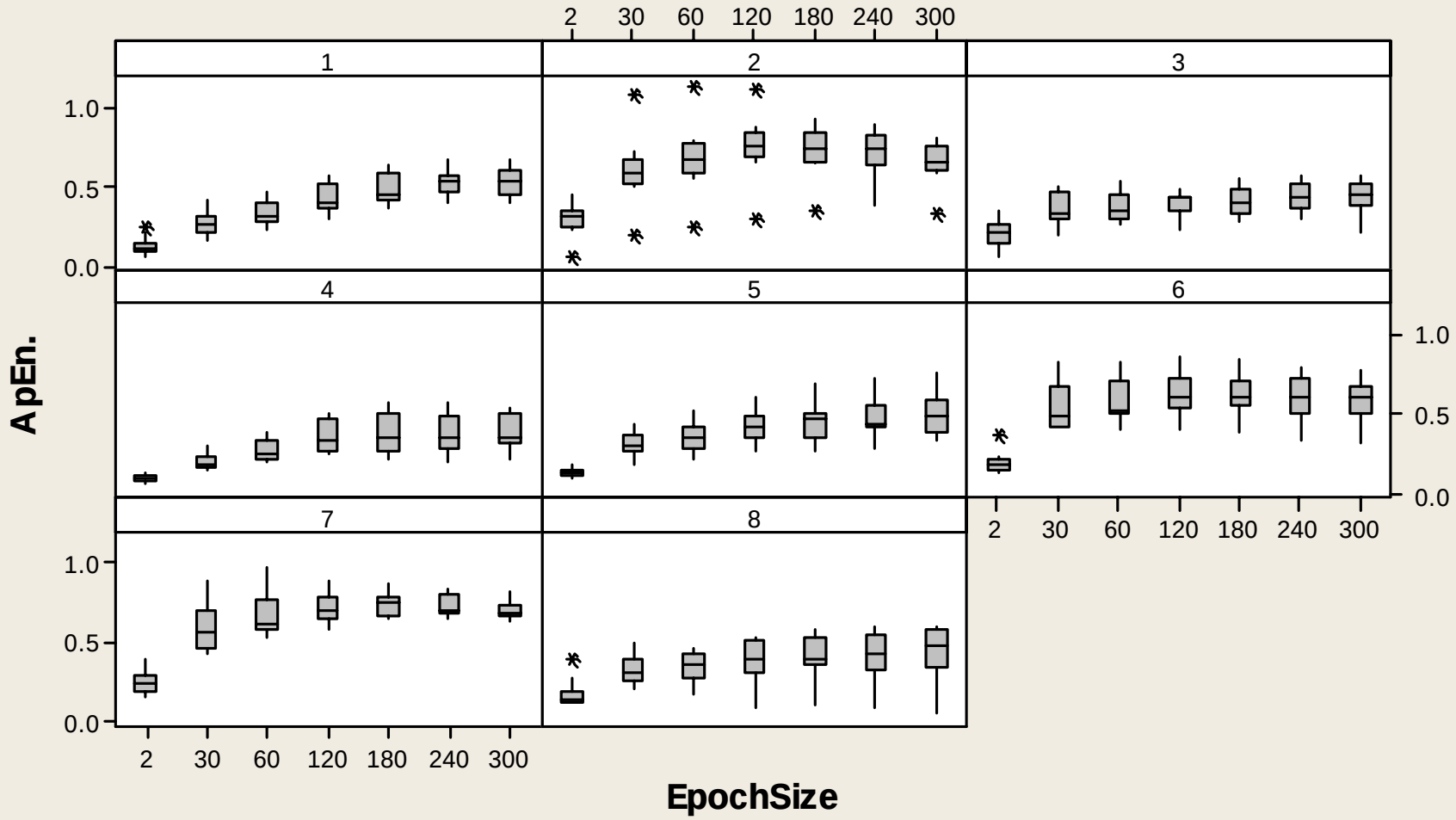
At 30 second and 1 minute epochs, the difference in entropy between days 7 and 8 is much greater than at epochs of 4-5 minutes, where the entropy is nearly identical



For epoch sizes 2 minutes or less, day 11 has more entropy than day 12. But for epochs larger than 2 minutes, day 12 has greater entropy. Which is right?

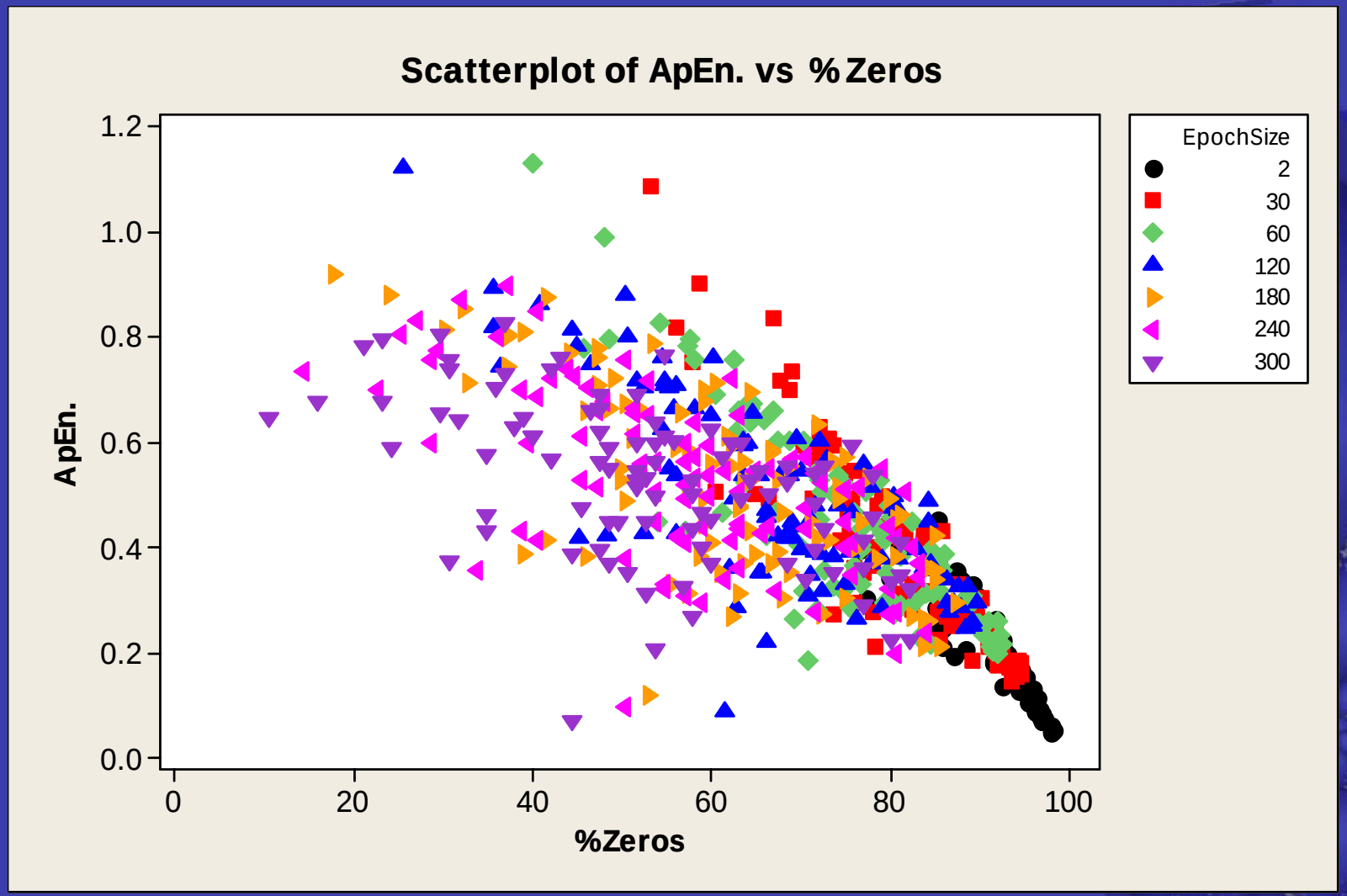


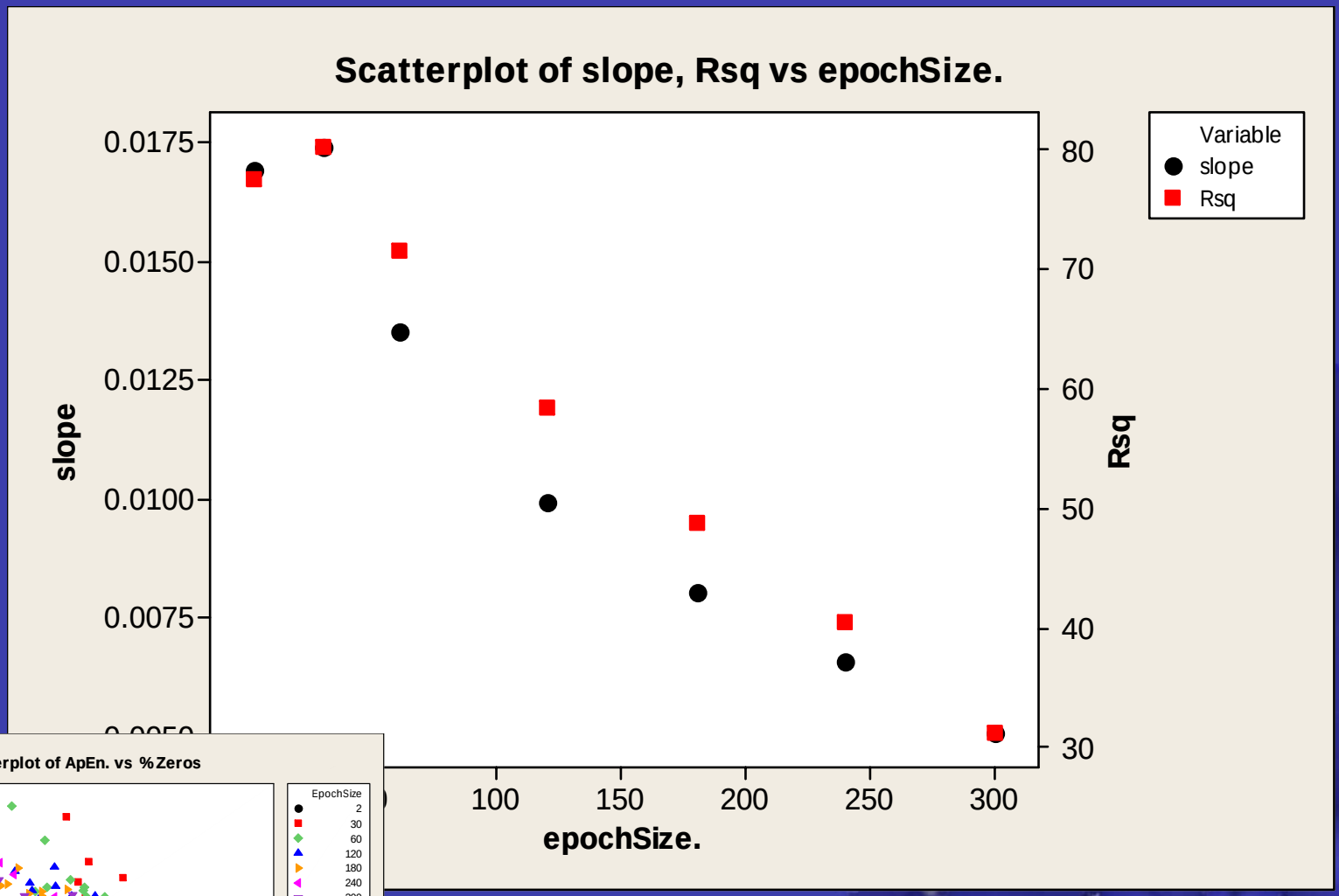
- Consistent for most days and subjects
- Is ApEn too sensitive to changes in Epoch Size
- Are there inherent properties of the mobility that determine the optimal epoch size?

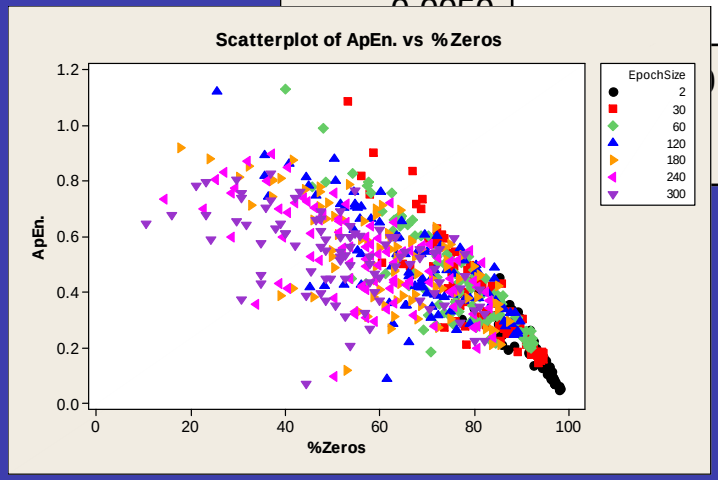


Panel variable: SubjCtr.

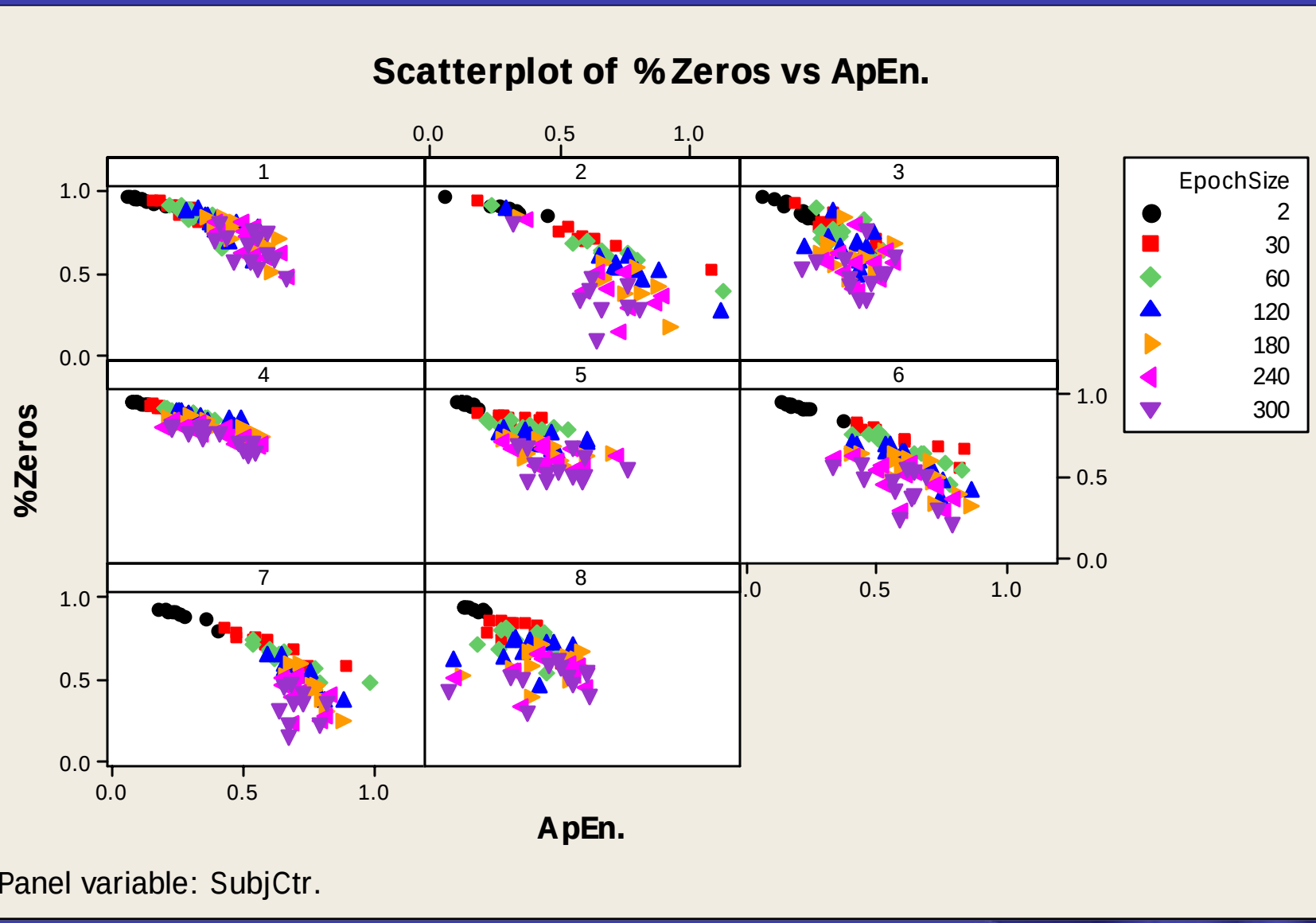
The influence of zero-count epochs on ApEn

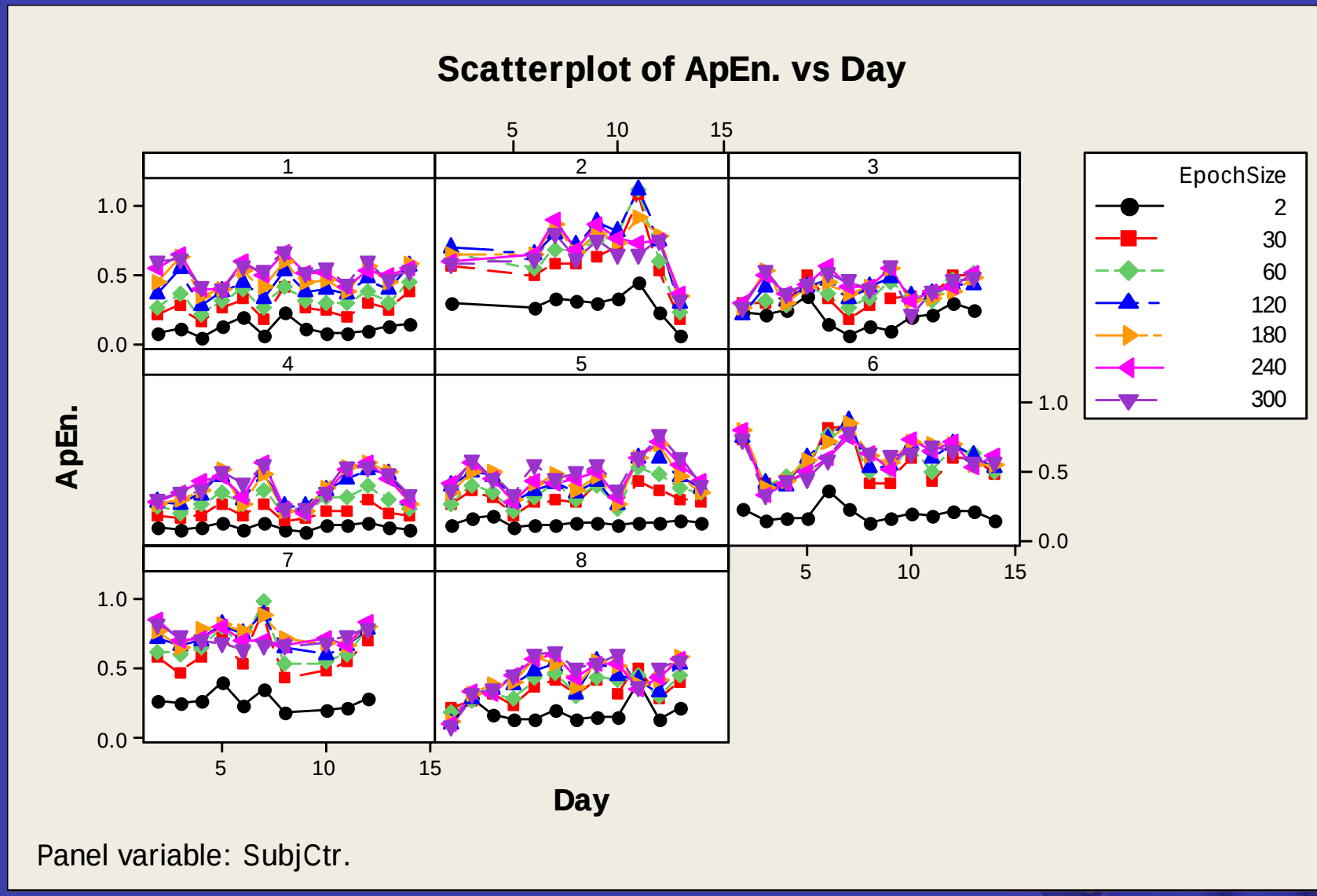






Regressions of ApEn on % Zero-Count Epochs for different Epoch Sizes


Scatterplot of %Zeros vs ApEn.
1
2
3
4
5
6
7
8
0.0
0.5
1.0
%Zeros
ApEn.
EpochSize
2
30
60
120
180
240
300
Panel variable: SubjCtr.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1.0
5
10
15

Entropy Results

- One minute epochs

PRE

POST

	ST32		ST34	
	Mean	Stdev	Mean	Stdev
Pre	0.619	0.222	0.364	0.083
Post	0.647	0.183	0.365	0.105

No change in ApEn with new wheelchair!

Future Direction

- Decide if ApEn can be used to describe mobility
- Select the optimal epoch size to analyze
- Identify “healthy” complexity by relating entropy to health and quality of life measures

Selected References

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Questions?