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

  – 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”

Innovative Analyses of Human Movement by Nicholas Stergiou
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*

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• 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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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?
The influence of zero-count epochs on ApEn

Scatterplot of ApEn. vs %Zeros

EpochSize
- 2
- 30
- 60
- 120
- 180
- 240
- 300
Scatterplot of slope, Rsq vs epochSize.

Scatterplot of ApEn vs %Zeros

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

- **One minute epochs**

<table>
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<tr>
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<th>ST32 Mean</th>
<th>ST32 Stdev</th>
<th>ST34 Mean</th>
<th>ST34 Stdev</th>
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<td>0.364</td>
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<tr>
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<td>0.183</td>
<td>0.365</td>
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</tr>
</tbody>
</table>

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

- Innovative Analyses of Human Movement, Nicholas Stergiou editor. 2004

Examples Cited
Acknowledgements

• Ideas and Discussion
  – Dr. Jim Cavanaugh
  – Dr. Helen Heonig
  – Dr. William Del'Aune
  – Dr. Fran Harris
  – Dr. Stephen Sprigle
  – Dr. Jeffrey Hausdorff
  – Dr. Young-Hui Chang and Applied Physiology 6232 class

• Funding Sources:
  – NSF GFRP
  – NIDRR - RERC Wheeled Mobility

• Instrumentation & Data Collection
  – Chris Maurer
  – Adrienne Davis
  – Shawn Lankton
  – Michelle Krueger

• Code
  – PhysioBank, PhysioToolkit, and PhysioNet
  – Jim Cavanaugh
Questions?