METHODS FOR ANALYSIS OF DAILY WHEELCHAIR ACTIVITY DATA

Sharon Eve Sonenblum
Georgia Institute of Technology, Atlanta, GA, USA
E-mail: sharoneve@gatech.edu

INTRODUCTION

Recent advances in technology, including accessibility of wireless sensors, improved memory size, low power consumption and longer battery life have resulted in the increased portability of activity monitors. Numerous commercial and custom products including pedometers, wheelchair odometers and accelerometer-based activity monitors allow research to take place beyond the laboratory. It is possible to monitor a subject in their home environment for weeks at a time. Although many medical interventions are meant to improve mobility and physical activity, improved gait in the laboratory does not necessarily translate to improved mobility at home. Therefore, the characterization of daily mobility is very important and raises many new questions including: How much data should be collected? How should it be analyzed? While common measures such as mean and standard deviation successfully describe the magnitude of the data, the temporal spread of activity may also be important. For example, 30-minute bouts of moderate to vigorous physical activity are recommended for health benefits. Alternatively, short bouts of movement may indicate environmental interactions and stationary activities. In wheelchair activity, long durations without activity may be detrimental to tissue loading and pressure ulcer outcomes.

Many methods for describing the temporal sequencing of data are described in the literature. Detrended fluctuation analyses, approximate entropy and power spectral analyses are a few examples that have been applied to gait. This discussion will be limited to the use of approximate entropy (ApEn), a measure of predictability or regularity described by Pincus in 1991. Specifically, ApEn "measures the logarithmic probability that a series of data points a certain distance apart will exhibit similar relative characteristics on the next incremental comparison" (Stergiou 2004).

This paper addresses questions that arise when applying ApEn to daily activity data such as: What is the appropriate epoch size (i.e., time over which activity events are summed) for analyzing the data? Are there inherent properties of mobility that effect the optimal epoch size? Is ApEn too sensitive to the epoch size to use for analysis of activity data? Two conflicting hypotheses of the influence of epoch size on ApEn are: 1) With *increasing* epoch size, there is more averaging of data so the ApEn should decrease. 2) With *decreasing* epoch size, there is an increase in the number of zero-count epochs (epochs containing no movement), which are inherently more predictable so the ApEn should decrease.

METHODS

We recruited seven upright power wheelchair users who had just been prescribed a new, tilt-in-space (TIS) wheelchair. Subjects' wheelchairs (first the upright and then the TIS 3 months after its delivery) were instrumented with an occupancy monitor, position sensor, and wheel odometer for 2 weeks. The total number of wheel counts was recorded every two seconds on a custom data logger.

ApEn(m,r) parameters were selected according to Stergiou 2004 as m=2 (observations to compare) and tolerance r =

0.2*stdev. This analysis considered the ApEn over the most active 8 hours per day for each subject. ApEn was calculated for the raw 2 second epoch, as well as for down-sampled epoch sizes of 30 sec, 1, 2, 3, 4 and 5 minutes. ApEn is meant to be used as a comparative measure (e.g. pre- and post-intervention). First, day-to-day differences were used to consider the effect of epoch size on ApEn. Then, ApEn was calculated with 1 minute epochs for the 2 subjects who have completed both phases of this study to compare ApEn across different wheelchairs.

RESULTS AND DISCUSSION

Subject 1's data (Fig 1, Left) illustrated a typical response of ApEn to epoch size over most subjects. The graphs suggest that zero-count epochs dominated the ApEn analysis. Analysis at all epoch sizes should produce approximately the same results for day-to-day comparisons. A few exceptions to this are also presented in Figure 1. ApEn was robust across different phases of data collection for the same subject (Table 1).

To further understand the influence of zero-count epochs, ApEn was regressed with percent zero-count epochs at each epoch size. With increasing epochs from 30s to 300s, the slopes decreased from 0.0174 to 0.00506 while the R^2 decreased from 0.80 to 0.31. Thus, the influence of percent zero-counts decreased with increasing epoch size.

Table 1: ApEn values differed between Subjects 2 and 3. Despite high day-to-day variability, ApEn was robust to two weeks in different wheelchairs and seasons.

	Subject 2		Subject 3	
	Mean	Stdev	Mean	Stdev
Pre	0.619	0.222	0.364	0.083
Post	0.647	0.183	0.365	0.105

SUMMARY/CONCLUSIONS

In general, ApEn was sensitive to epoch size but comparative relationships tended to be consistent across epoch sizes. It is open for discussion whether ApEn is too sensitive to use for analysis of daily activity data given the few conflicting cases. It is likely that the differences may be acceptable when taken in context of the research question. For example, large epochs might be needed to determine if wheelchair activity is sufficiently spread over the day to prevent excessive tissue loading. On the other hand, stepping activity may require smaller epochs to distinguish between simple repeated paths and more complex paths consisting of many direction and speed changes.

REFERENCES

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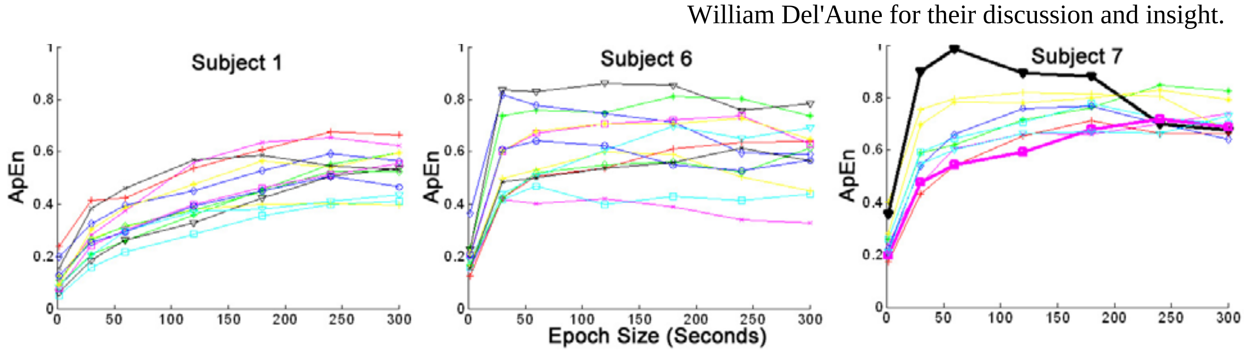

Figure 1: ApEn (plotted over multiple days) typically increases with epoch size (Subject 1, Left). At least one subject (6, Center), shows no increase in ApEn with epochs larger than 2s. For Subject 7 (Right), comparison of days 7 (black) and 10 (magenta) lead to different conclusions depending on epoch size.