Recurrence Quantification Reveals How Motor Development Disrupts Infant Sleep Through Movement

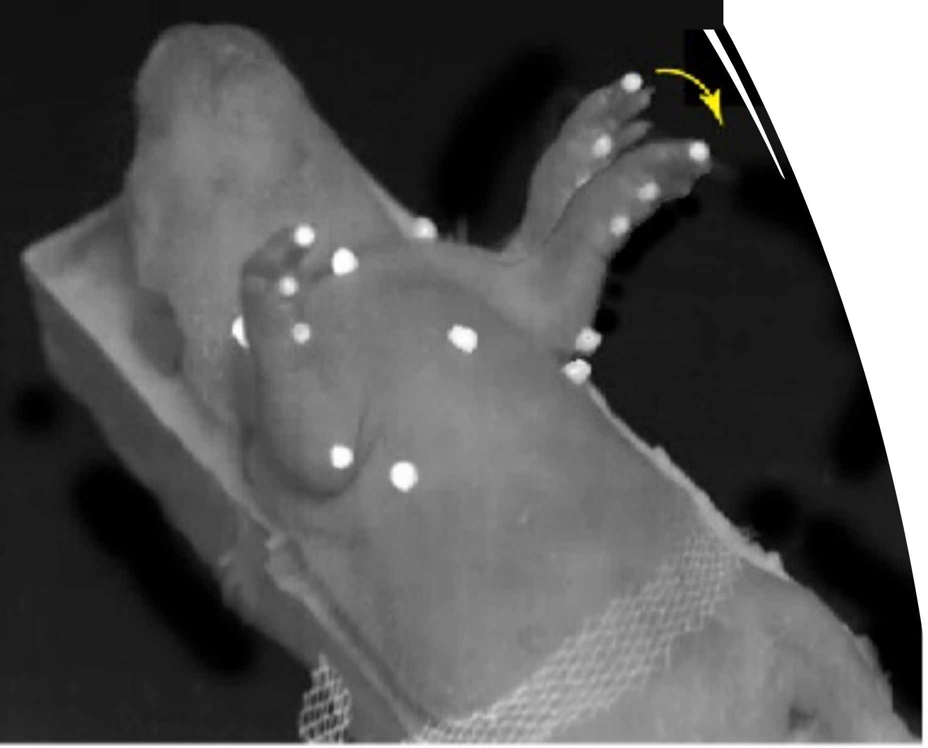
13th Annual Psychology Research Day 2022

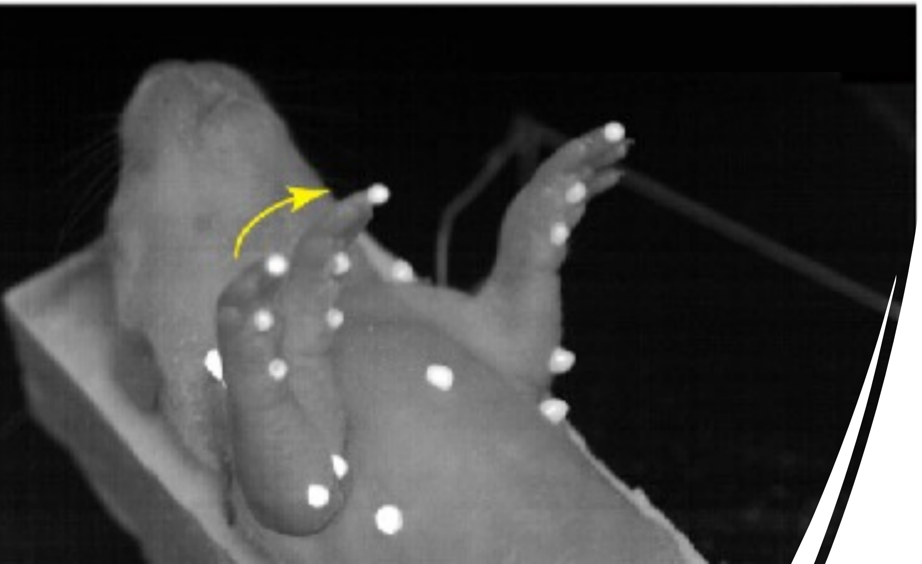
Aaron DeMasi

Motor Skill Acquisition and Development

New motor skills impact development

- Field of vision expands when infants learn to turn their head, sit independently, & stand (Franchak et al., 2018; Lima-Alvarez et al., 2014)
- Vocalization decreases while crawling or pulling-to-stand within the first couple of weeks of learning those skills (Berger et al., 2017)
- Crawling infants have more fragmented sleep & more activity during sleep, than age-matched non-crawlers (Scher, 2005; Scher & Cohen, 2005)





Why Motor Skill Impacts Sleep

- Movement?
  - Sleep-dependent muscle twitches are important for sensorimotor development (Blumberg, 2010; Khazipov et al., 2004)
  - Spontaneous twitching during REM maps limb movements to cortex (Blumberg et al., 2013; Mohns & Blumberg, 2010)
  - Infants may learn about their bodies by moving during sleep (Sokoloff et al., 2020)

Questions

1. How does motor development relate to infants’ nightly sleep fragmentation & nighttime motor activity?

2. How might motor development relate to the temporal dynamics of nighttime motor activity?

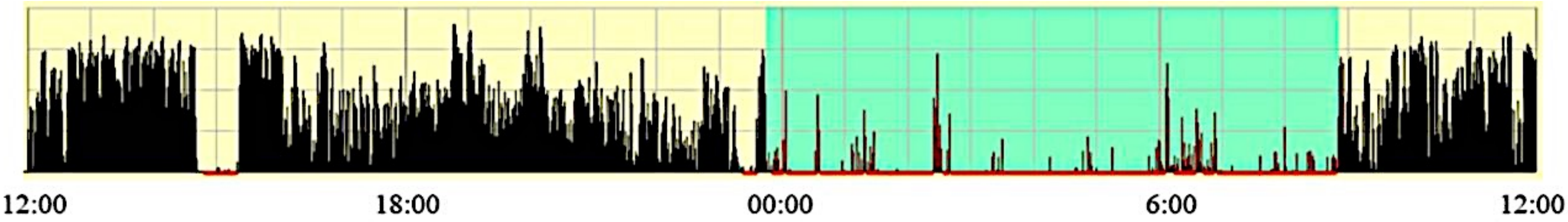
Method

- 78 infants (10-18 months of age) with varying walk experience had their sleep measured using actigraphy
- Parents provided the exact date of the first day their infants could walk > 10 feet
- Walk experience was calculated from the first day infants could walk until the night of sleep measurement

Analyses

- Recurrence quantification analysis (RQA) was run on each infants' individual time series of minute-by-minute movement during sleep
- Used parameters suggested in Calderón-Juárez et al. (2020)

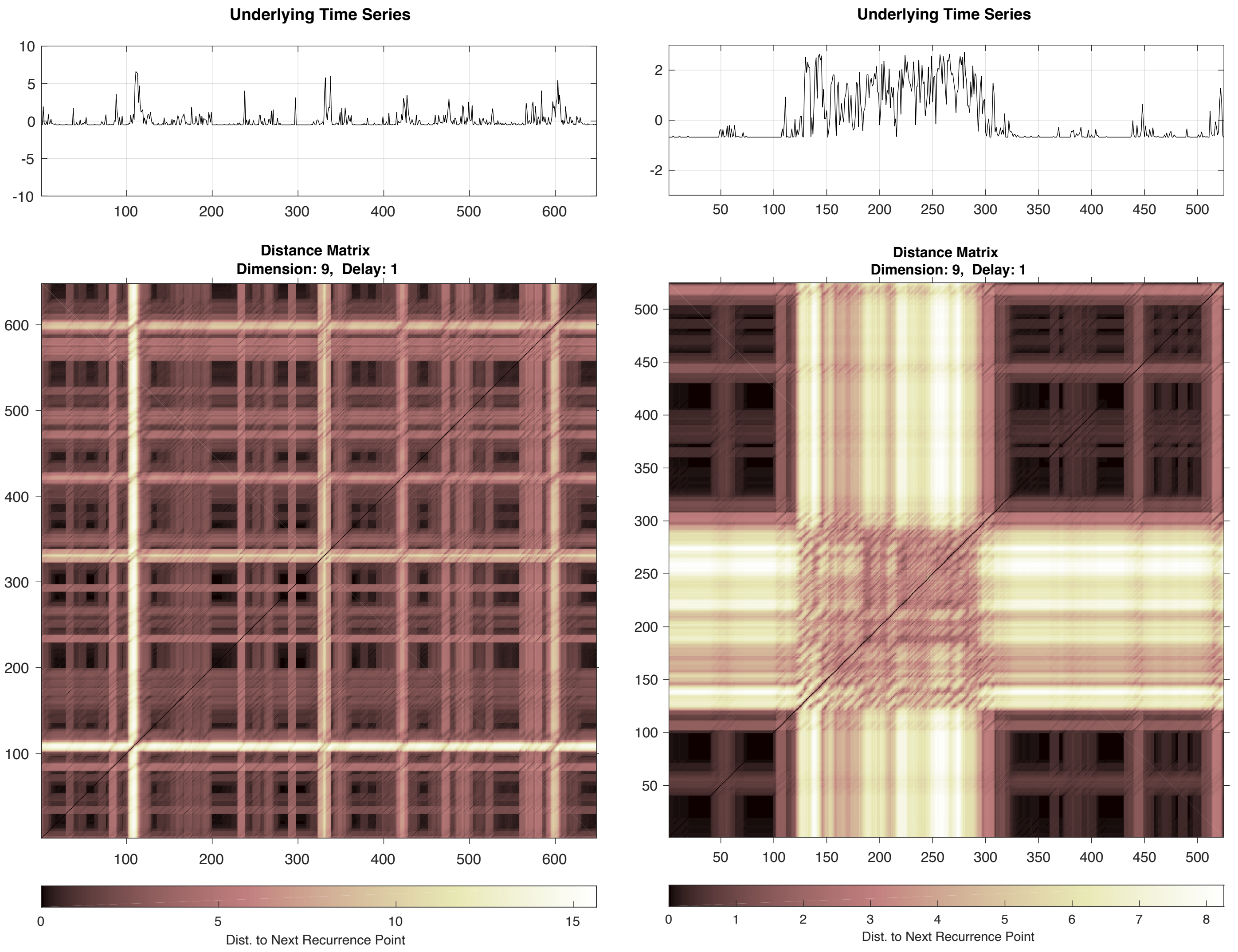
Example of actigram



RQA

- Percent determinism %DET of physical activity during sleep was computed from recurrence plots (RP)

- A measure of how recurrent & "law-governed" the activity in a system is over time (Papaioannou et al., 2019; Terrill et al., 2010)



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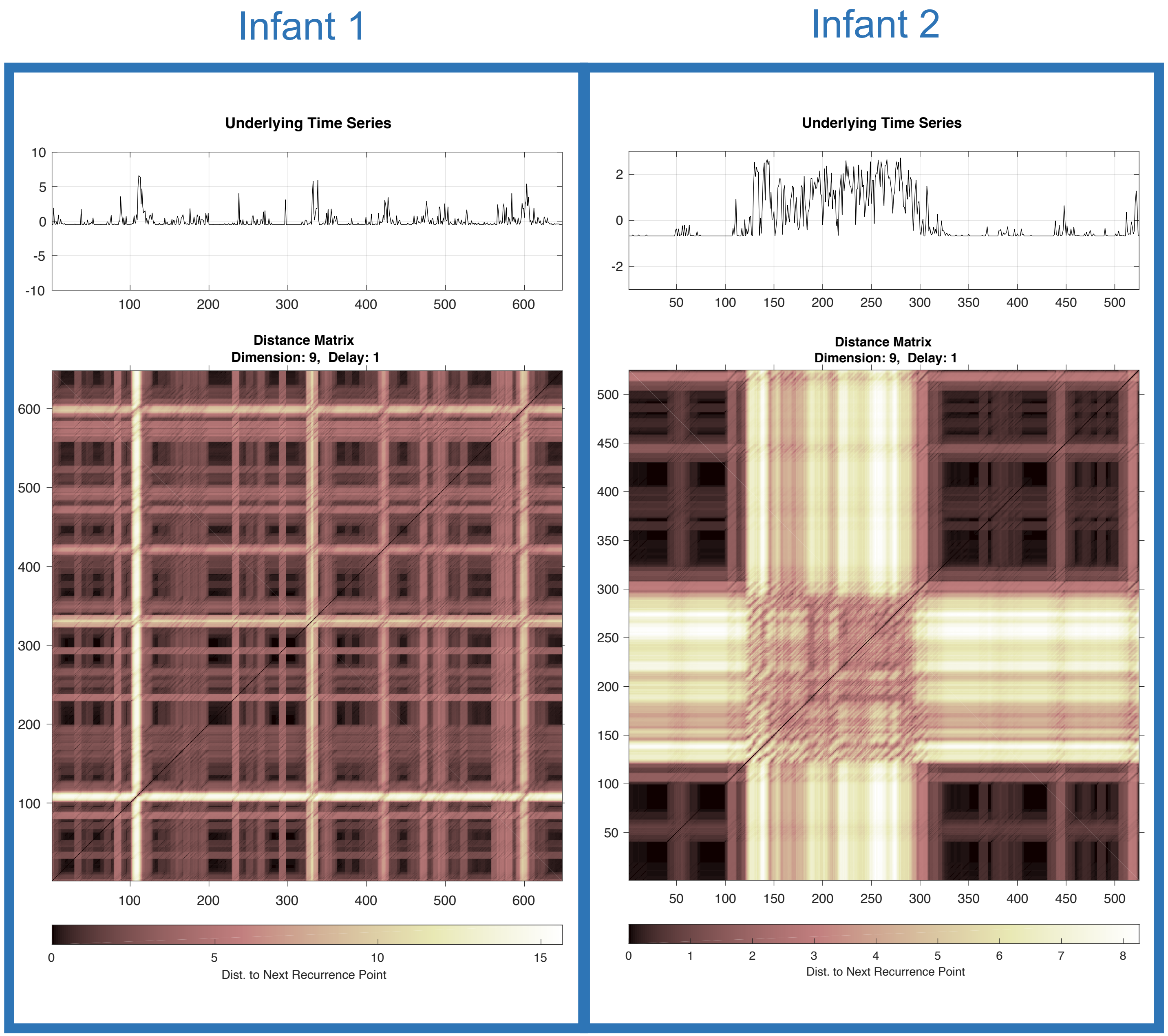

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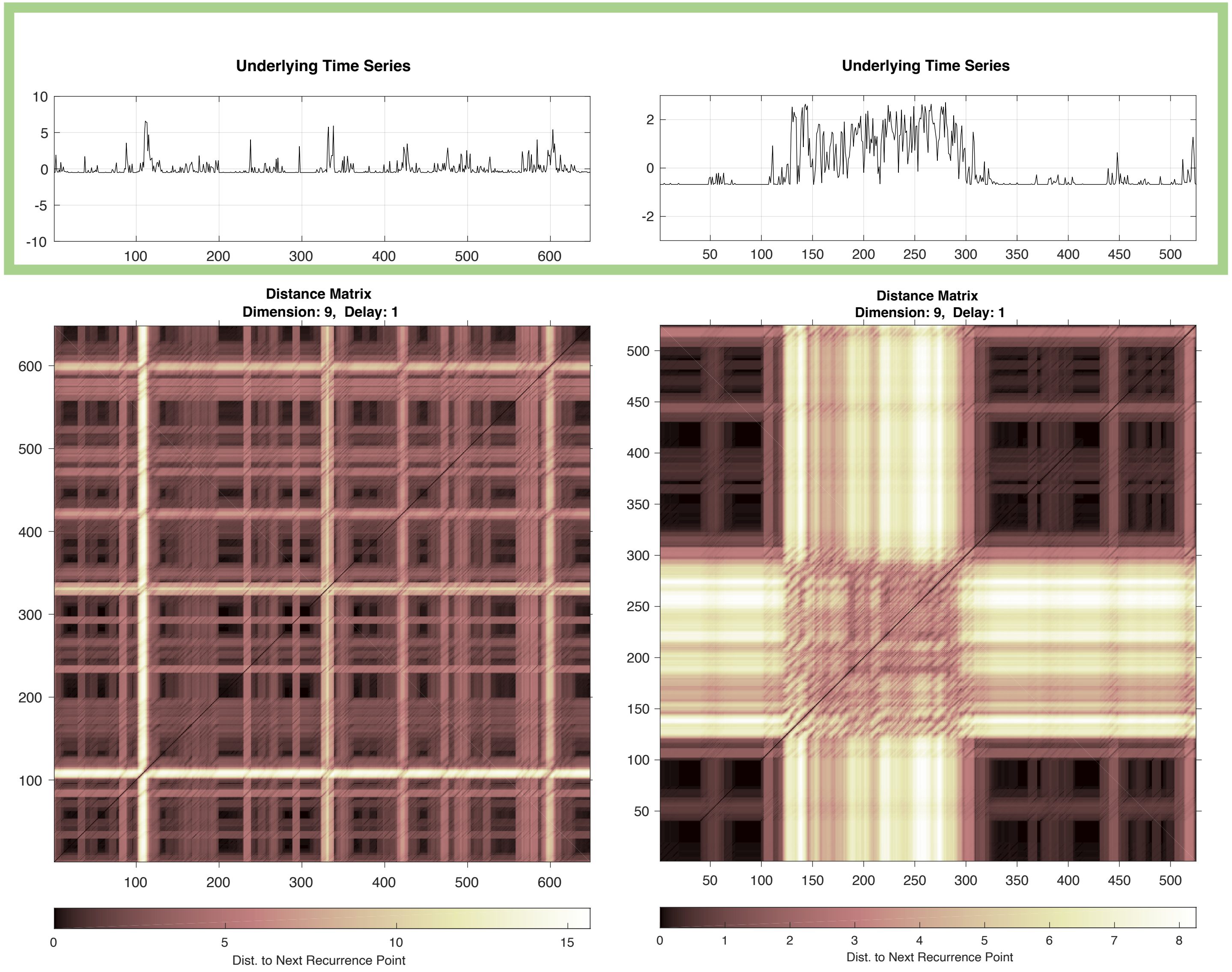
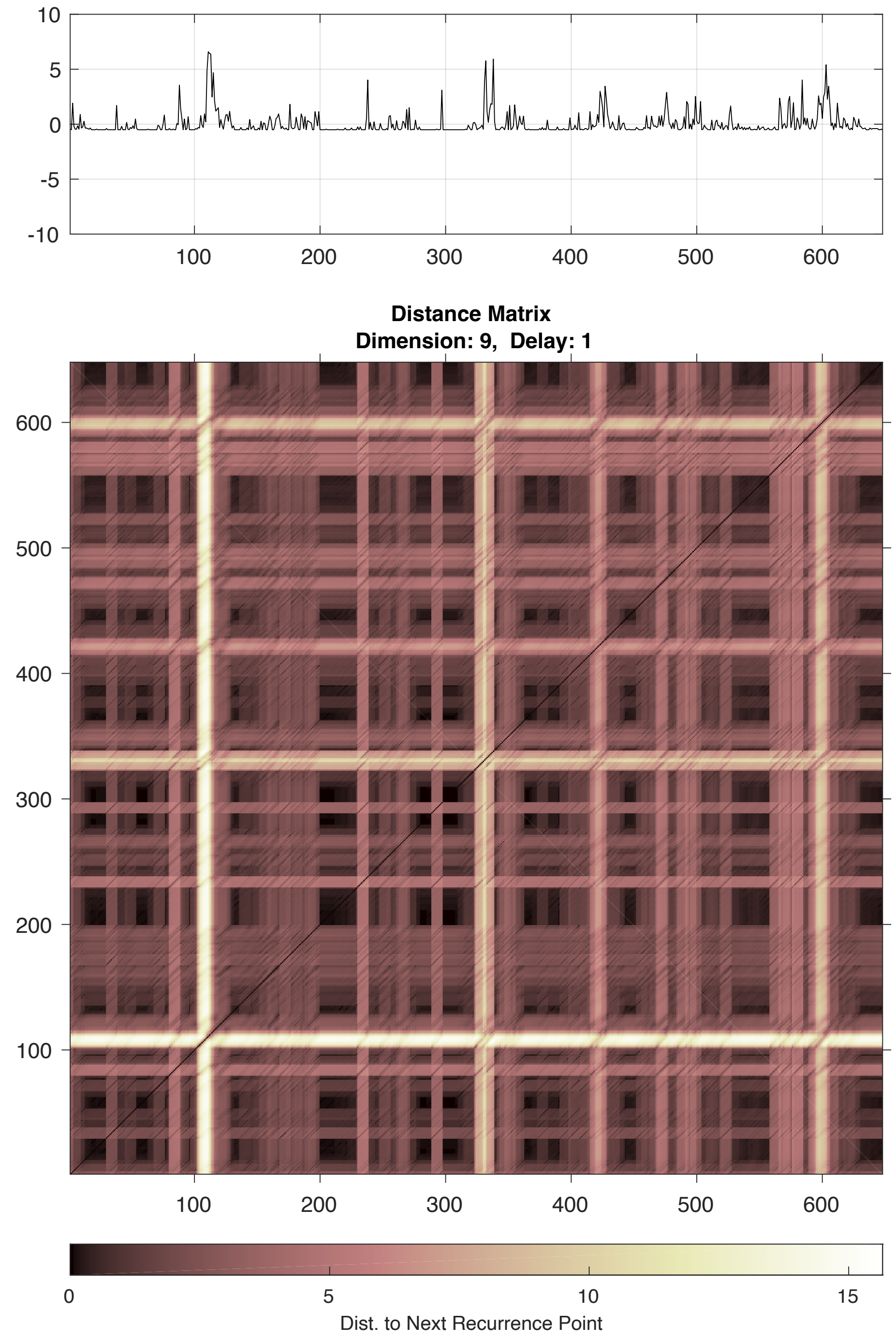
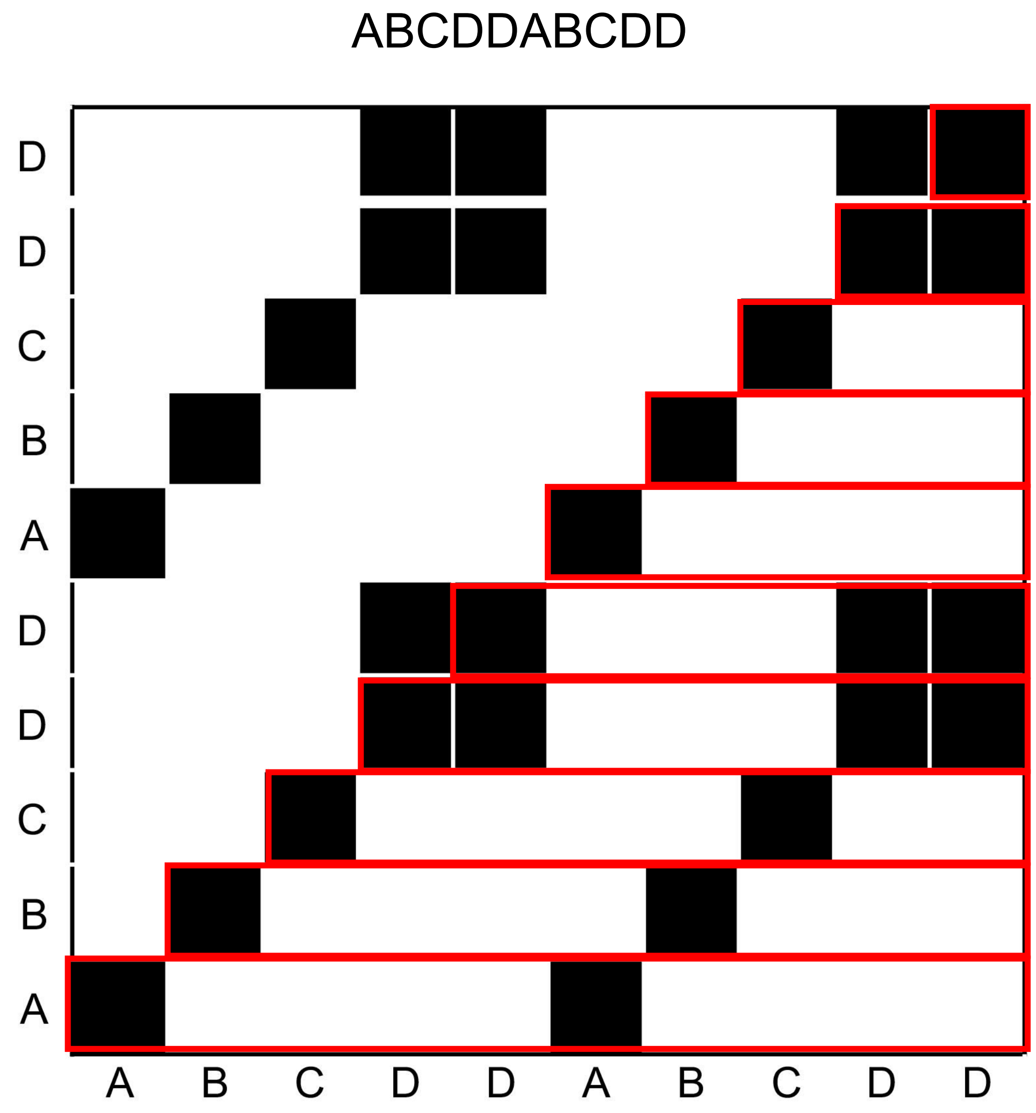



Distance Matrix
Dimension: 9, Delay: 1
Dist. to Next Recurrence Point


ABCDDABCDD
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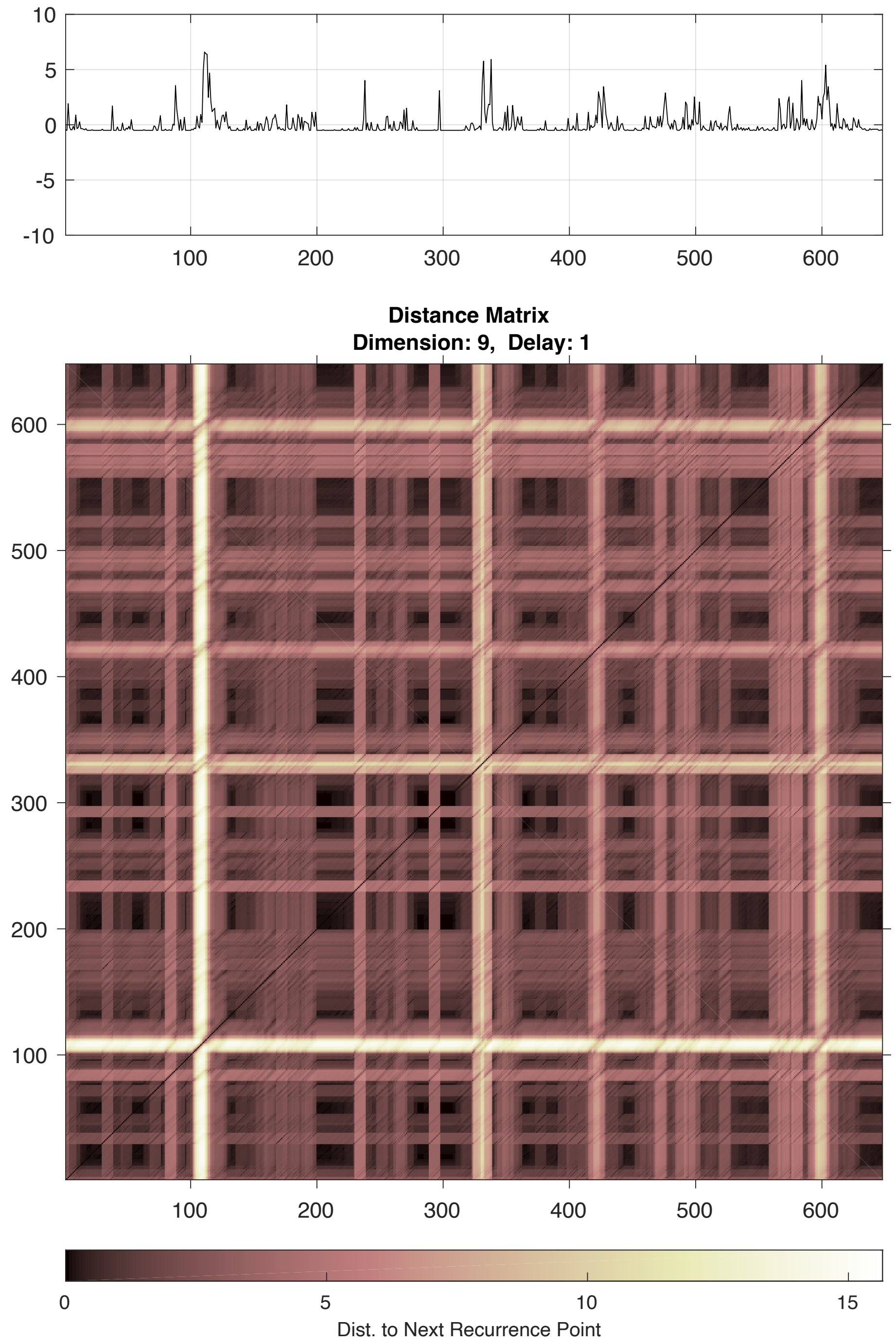
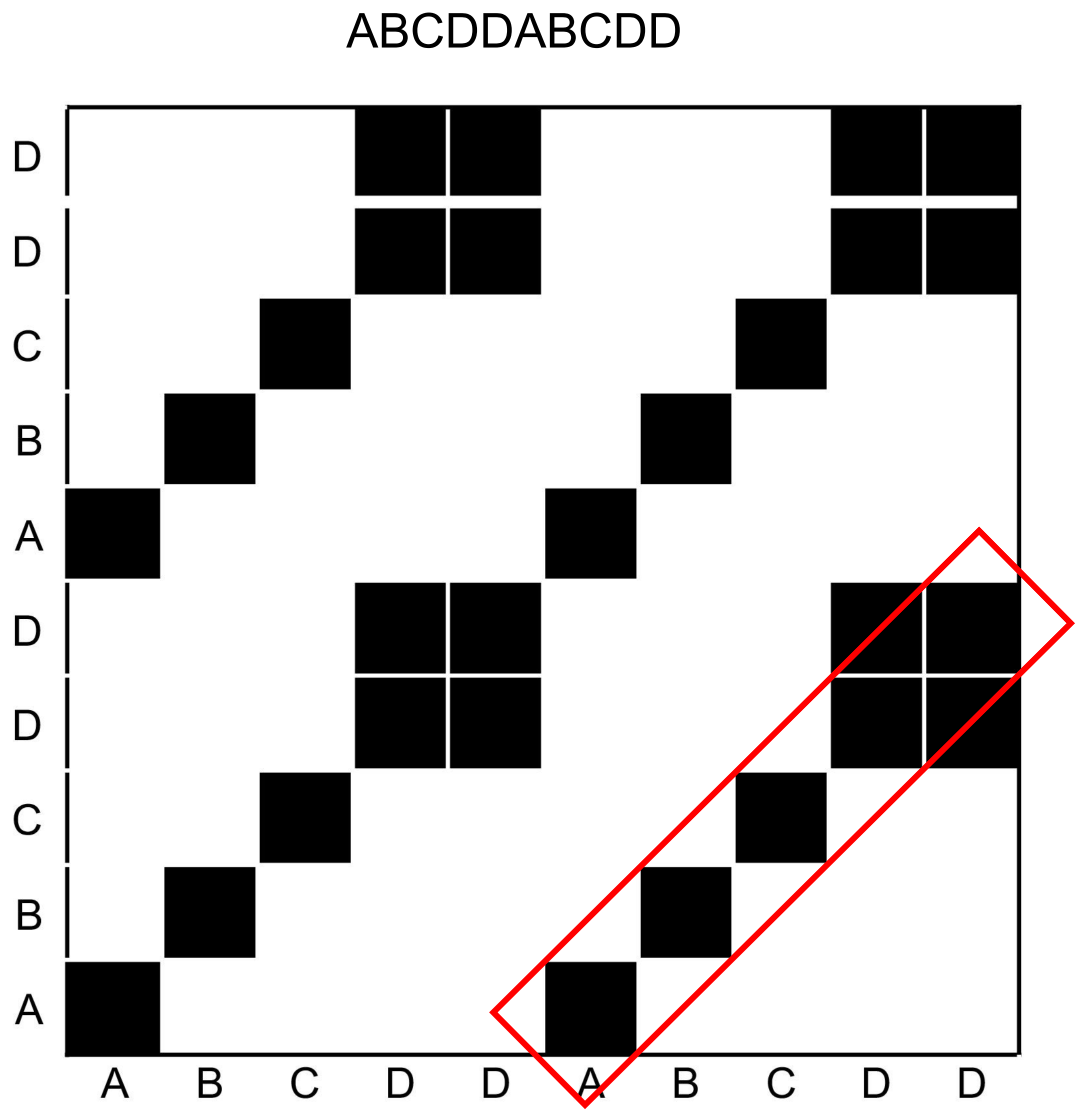
A
A B C D D A B C D D


10
5
0
-5
-10
100
200
300
400
500
600
Distance Matrix
Dimension: 9, Delay: 1
600
500
400
300
200
100
100
200
300
400
500
600
0
5
10
15
Dist. to Next Recurrence Point


ABCDDABCDD
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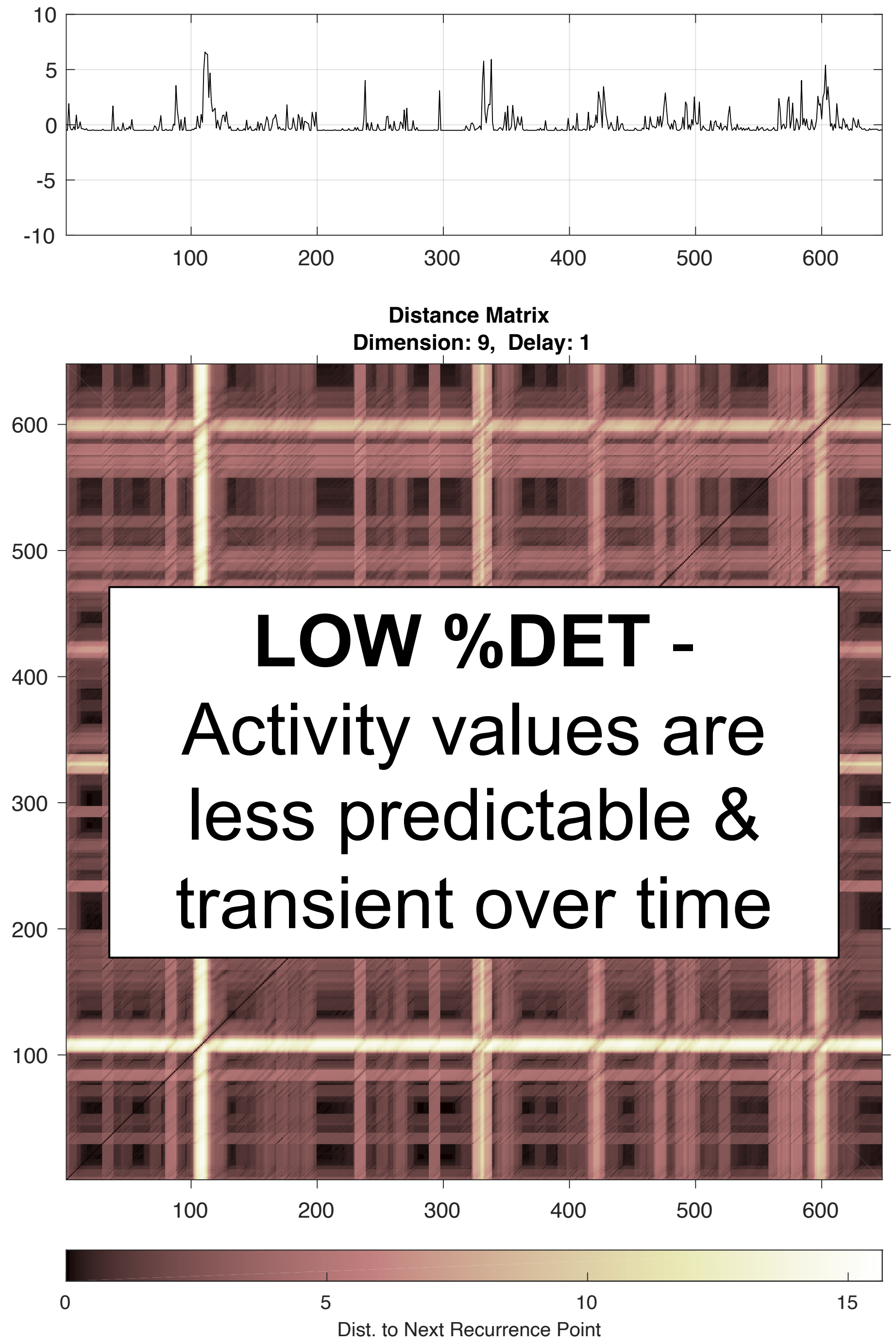
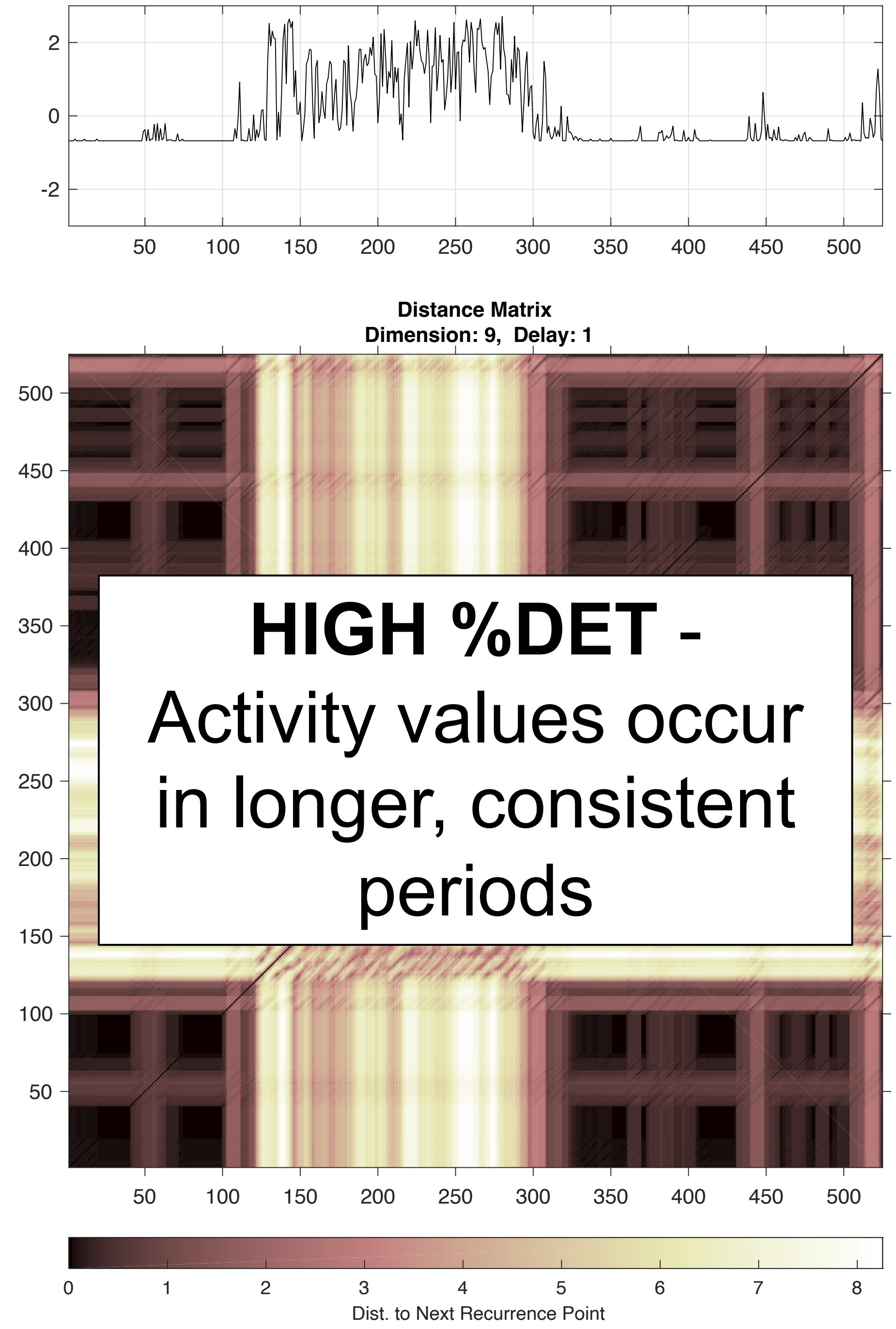

10
5
0
-5
-10
100
200
300
400
500
600
Distance Matrix
Dimension: 9, Delay: 1
LOW %DET -
Activity values are less predictable & transient over time
0
5
10
15
Dist. to Next Recurrence Point

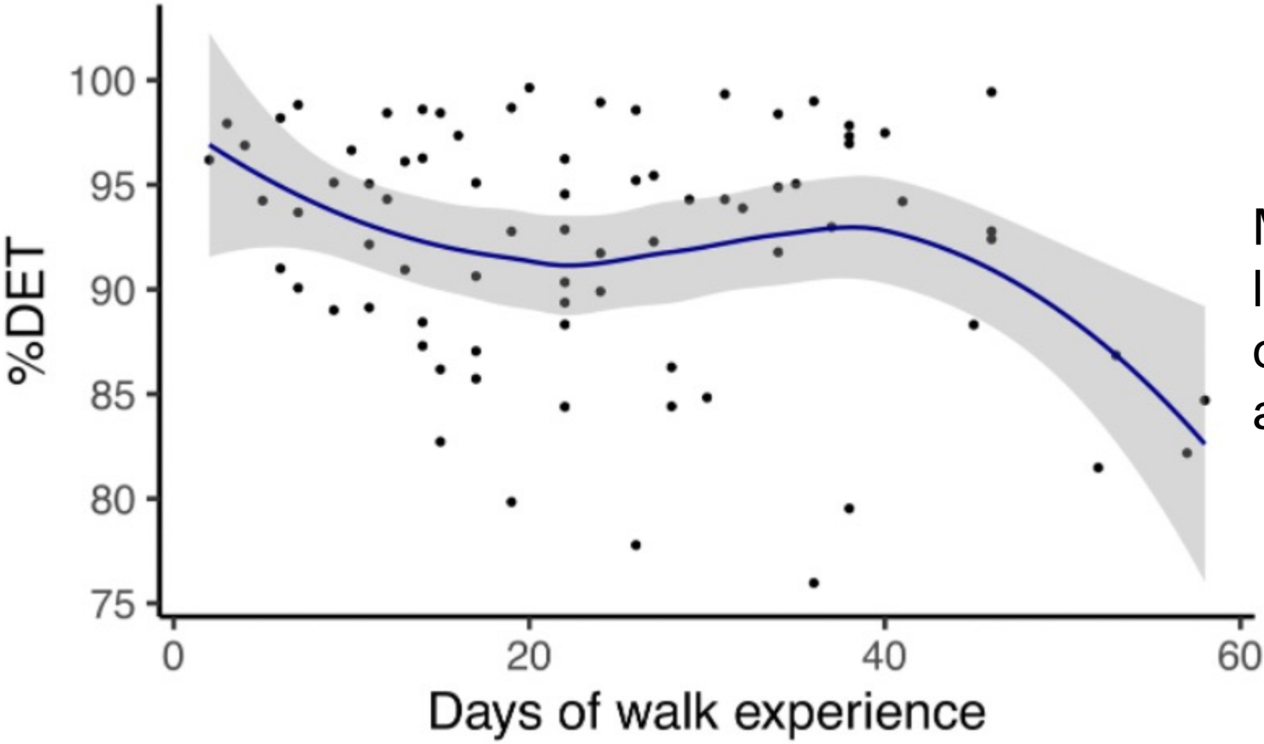

2
0
-2
50
100
150
200
250
300
350
400
450
500
Distance Matrix
Dimension: 9, Delay: 1
HIGH %DET -
Activity values occur in longer, consistent periods
0
1
2
3
4
5
6
7
8
Dist. to Next Recurrence Point

Results

- Walk experience unrelated to sleep & mean physical activity
- However, we compared our infants amid walking acquisition and a group of typically developing 14-month-olds (Scher, 2012)
- Our sample of newly walking infants had more wake episodes than the population estimate (mean difference = 3.87, 95% CI = 3.47 to 4.27, $p < .001$)
- New walkers had lower sleep efficiency than the population estimate (mean difference = -13.34%, 95% CI = -15.37 to -11.31, $p < .001$) and more physical activity during sleep than the population estimate (mean difference = 3.86, 95% CI = 1.72 to 6.01, $p < .001$)
- Sleep duration did not differ between our sample and the population estimate (mean difference = 2.04 minutes, 95% CI = -18.44 to 22.52, $p = .84$)

Results

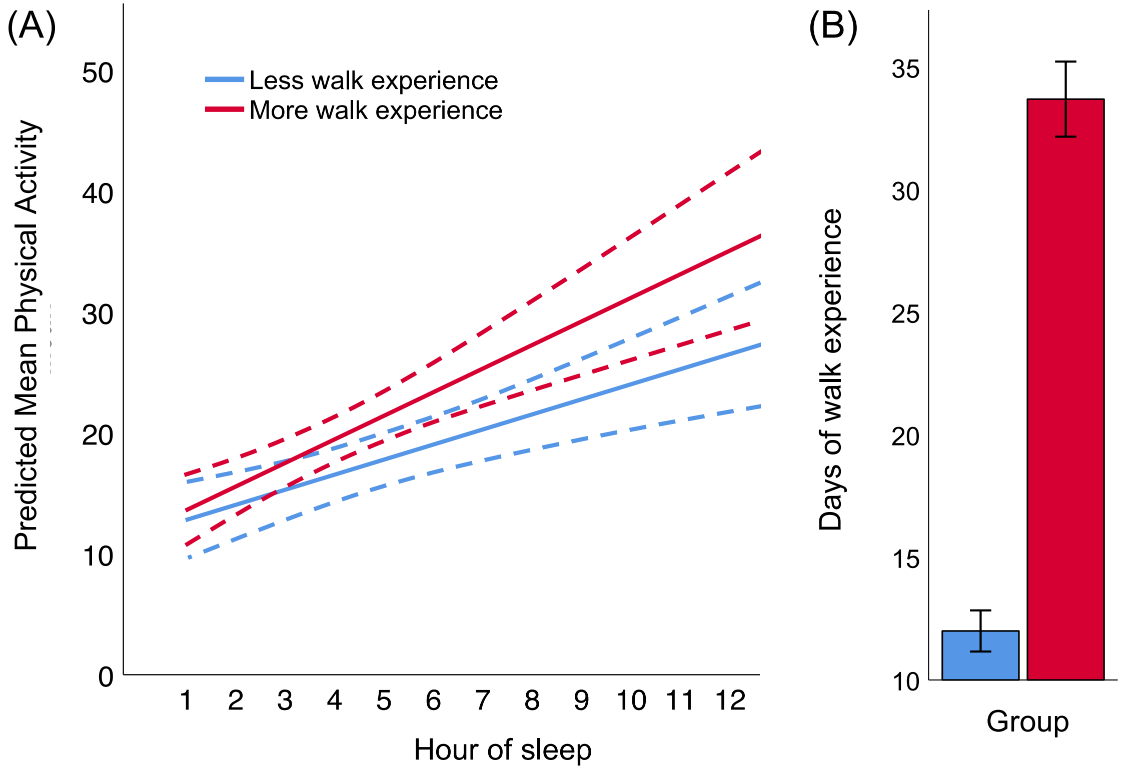
- With increasing walk experience, there was a decrease in %DET ($R = -.23$, $p = .04$)
- Age had no impact on %DET



More walk experience, less temporally organized/repetitive activity at night

Results

- A median split sorted infants into two groups (*Mdn* = 22 days of walk experience). Infants with more walk experience had a steeper hourly increase in movement ($\beta = 1.95$, $p < .01$) than infants with less ($\beta = 1.25$, $p < .01$)



Discussion

- A steeper increase in motor activity reflects a higher likelihood for infants to wake as the night progresses
  - Motor development helps infants escape the “pit of deep sleep”? (Klemm, 2011)
- Because improvements in walking skill continue 3-4 months after initial walk onset (Adolph et al., 2003), determinism of movement during sleep could reflect continued mastery of walking
  - temporal aspects of movement related to brain development

Limitations

- Walk experience (days)
  - Rough estimate
  - Restricted to new walkers
- Actigraphy
  - Differences in limb activity (Atun-Einy et al., 2018)

Future Directions

- Walk experience (days)
  - Add better measure of skill/experience
  - Expand study to age-matched, experienced walkers
- Actigraphy
  - Two actigraphs, one for each leg
  - Measure coupling between leg activities

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