

Individual Differences in Daily Rhythms of Cognitive Function

Emorie D. Beck, Ph.D

University of California, Davis

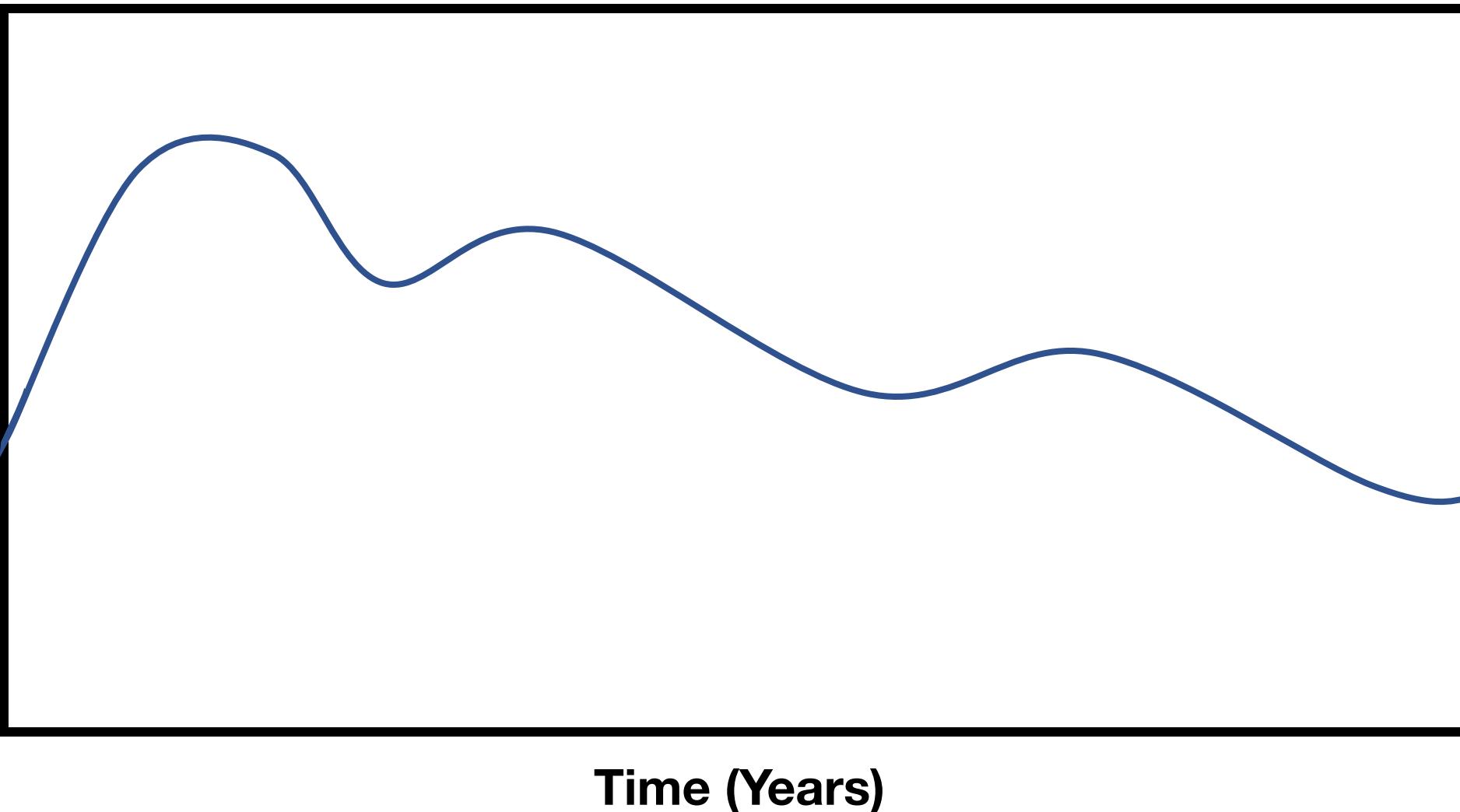
 @EmorieBeck

Zoë W. Hawks, Ph.D

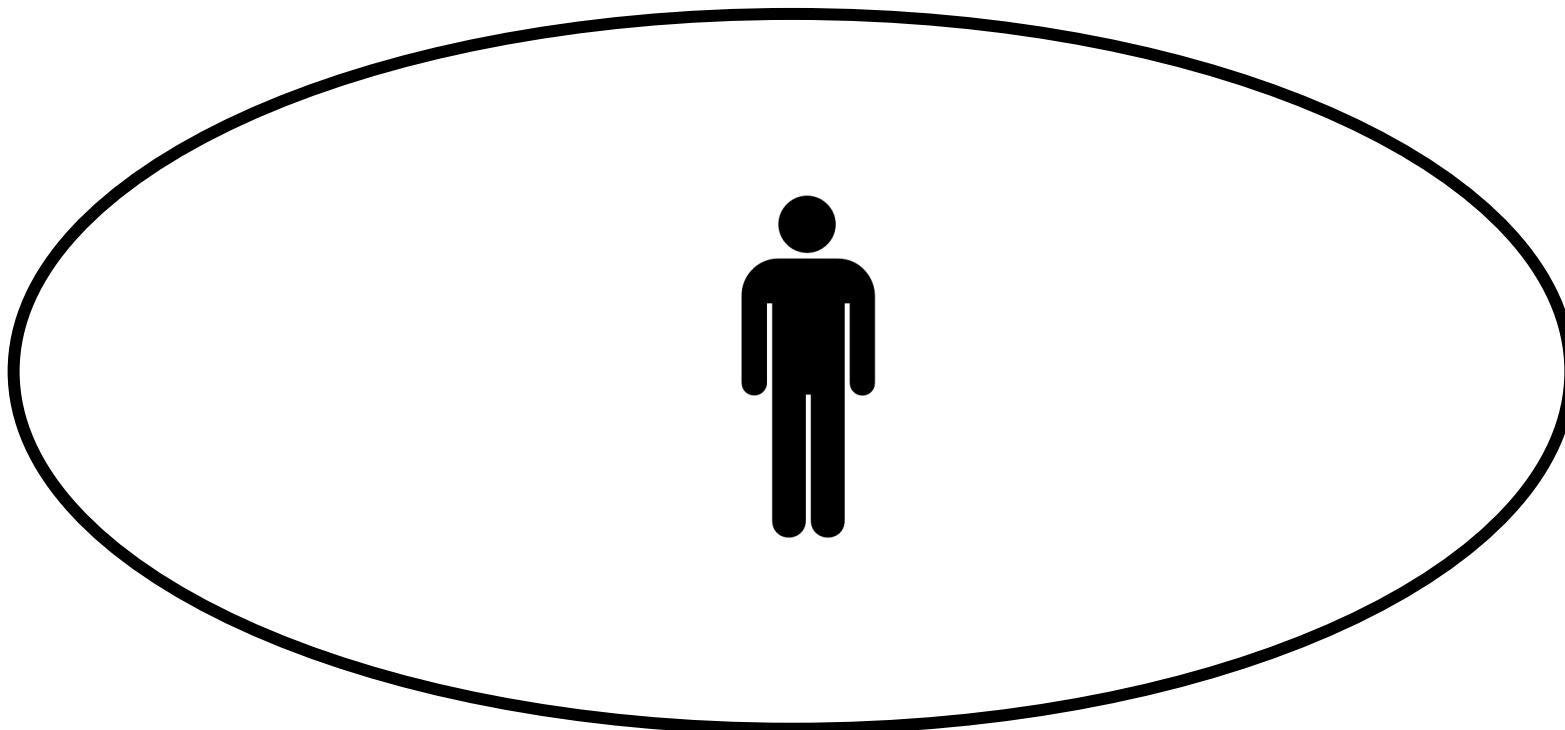
Daniel K. Mroczek, Ph.D

Eileen K. Graham, Ph.D

Lifespan Cognitive (Level) Decline



Persons in Context

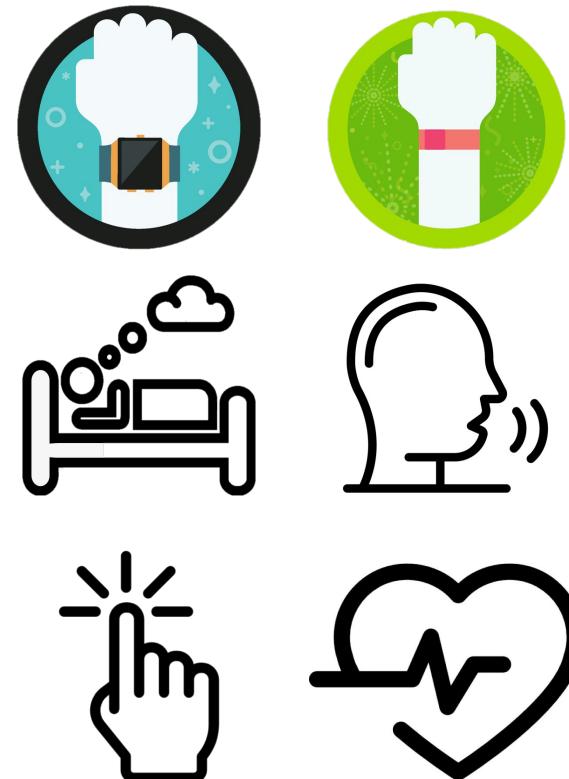
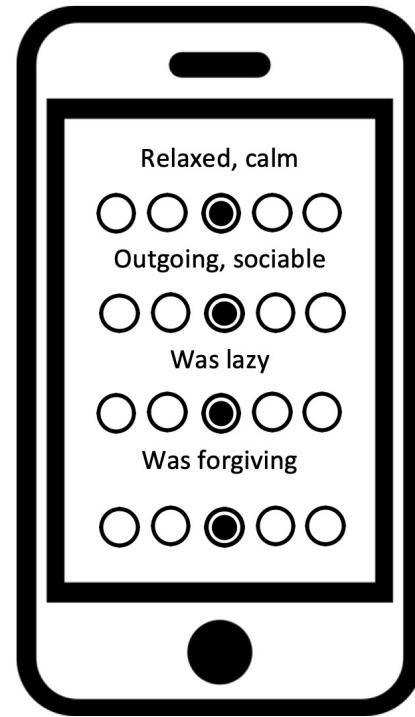


e.g., Lewin, 1936

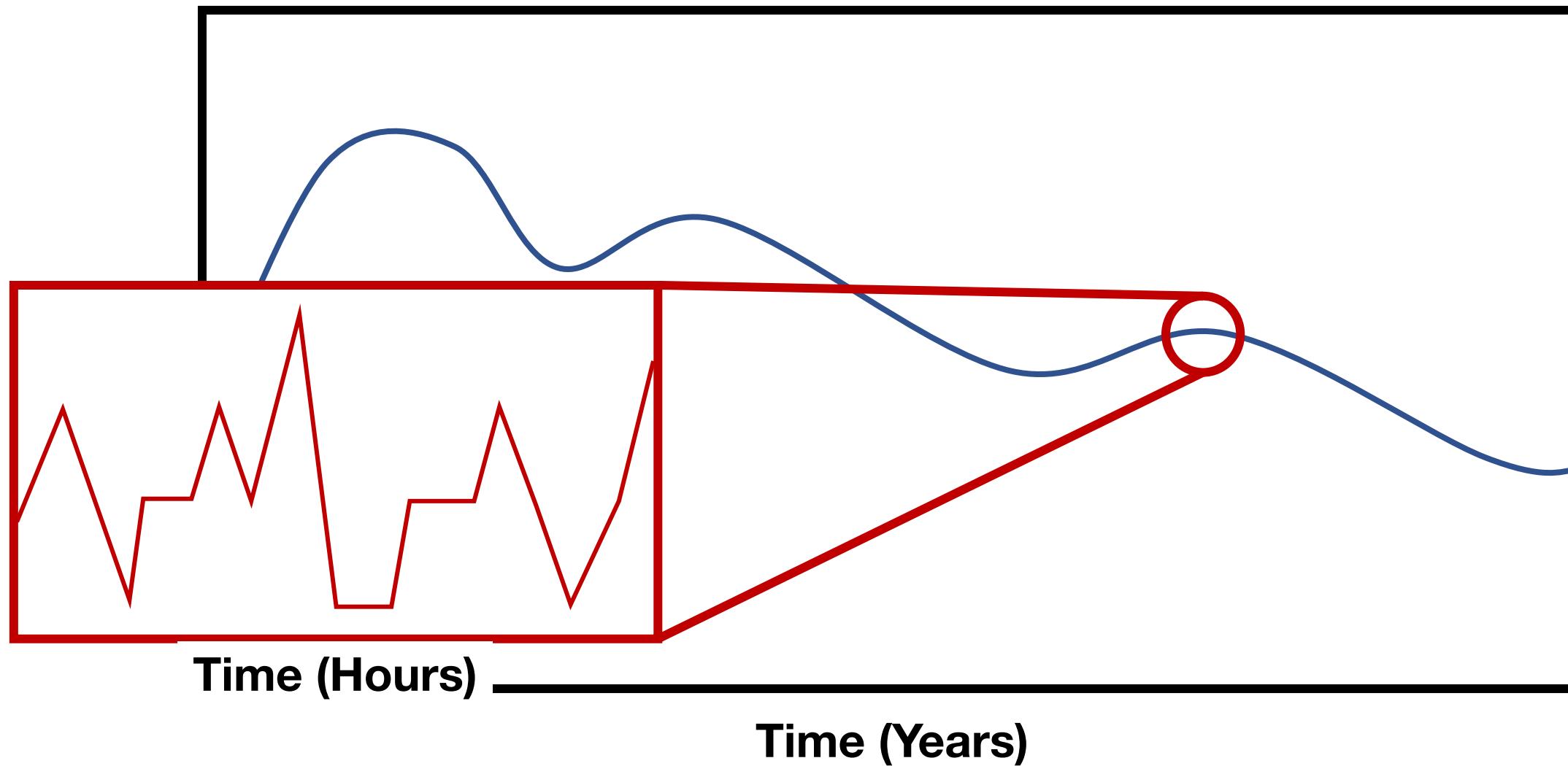
Lifespan Cognitive Variability

ESM / EMA

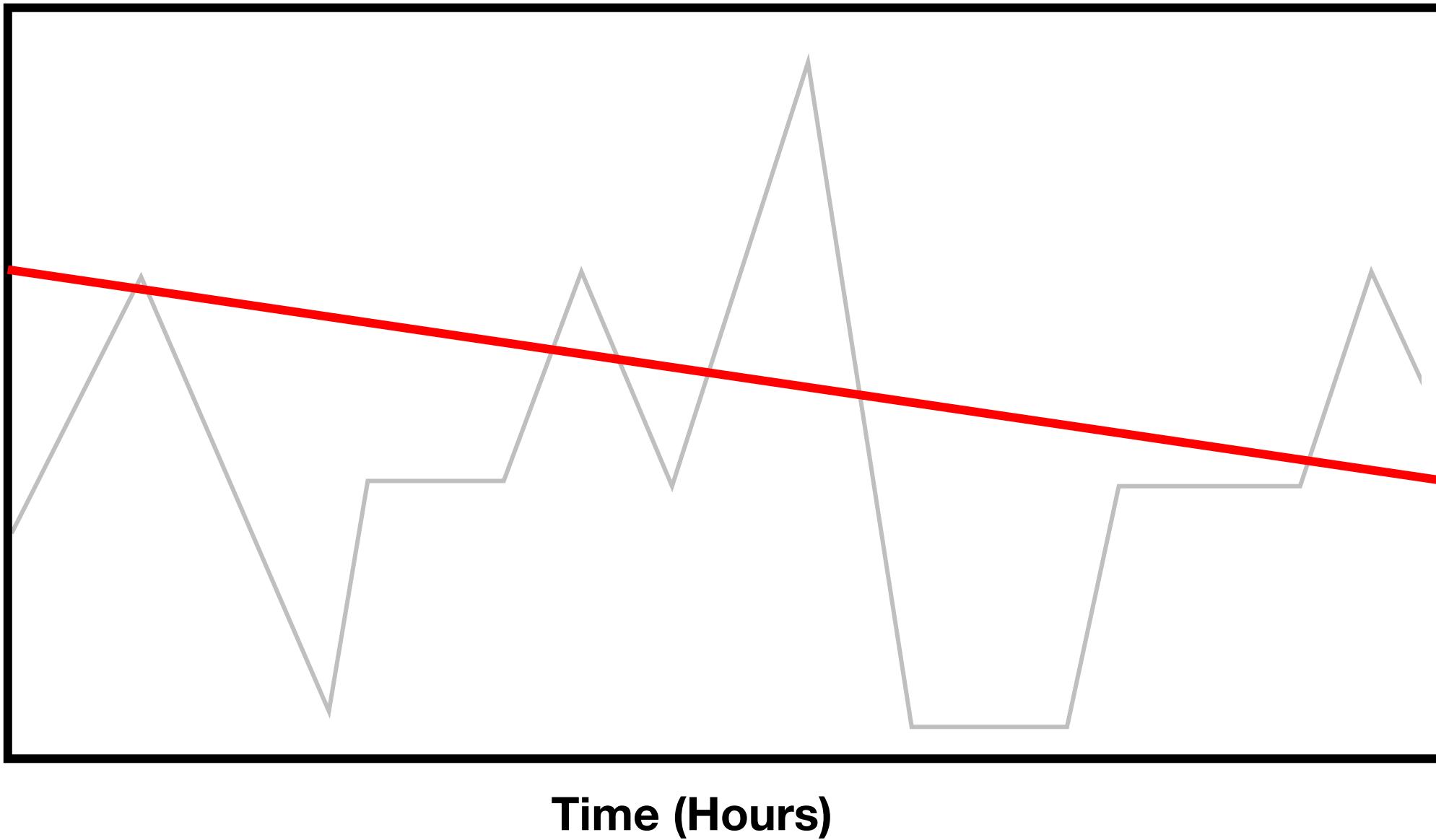
Mobile
Sensing



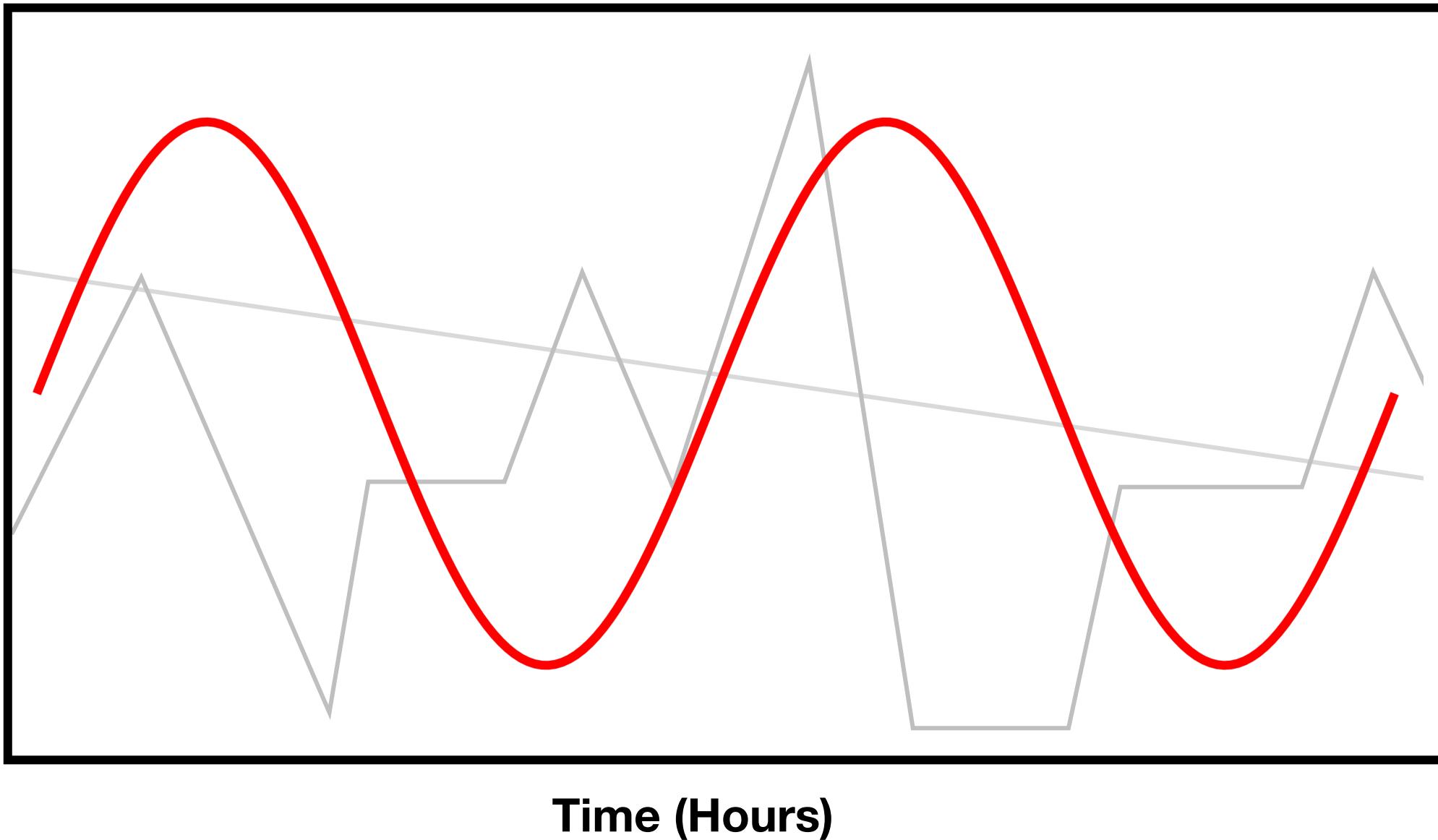
Lifespan Cognitive Variability



Lifespan Cognitive Variability



Lifespan Cognitive Variability

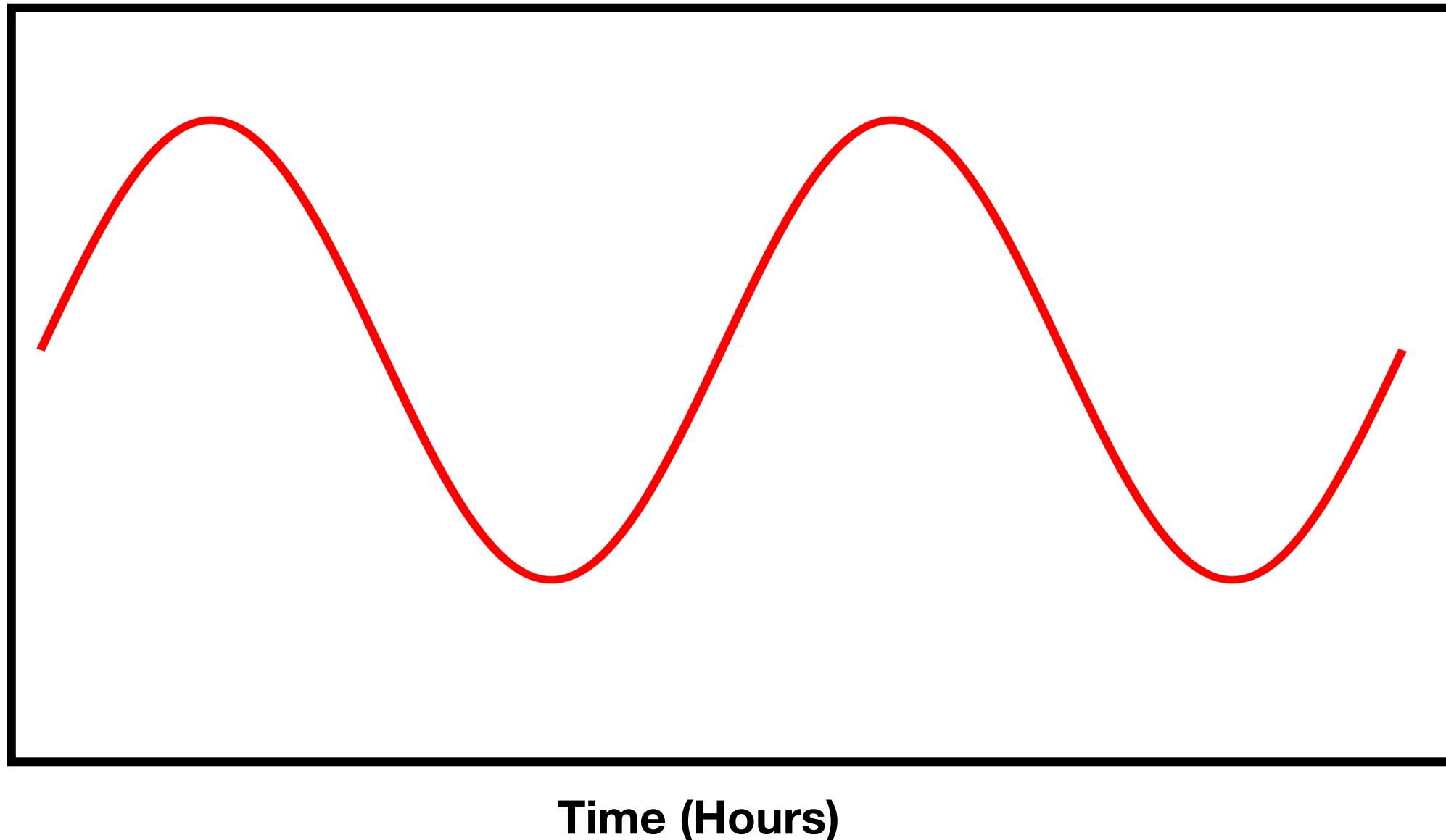


Lifespan Cognitive Variability

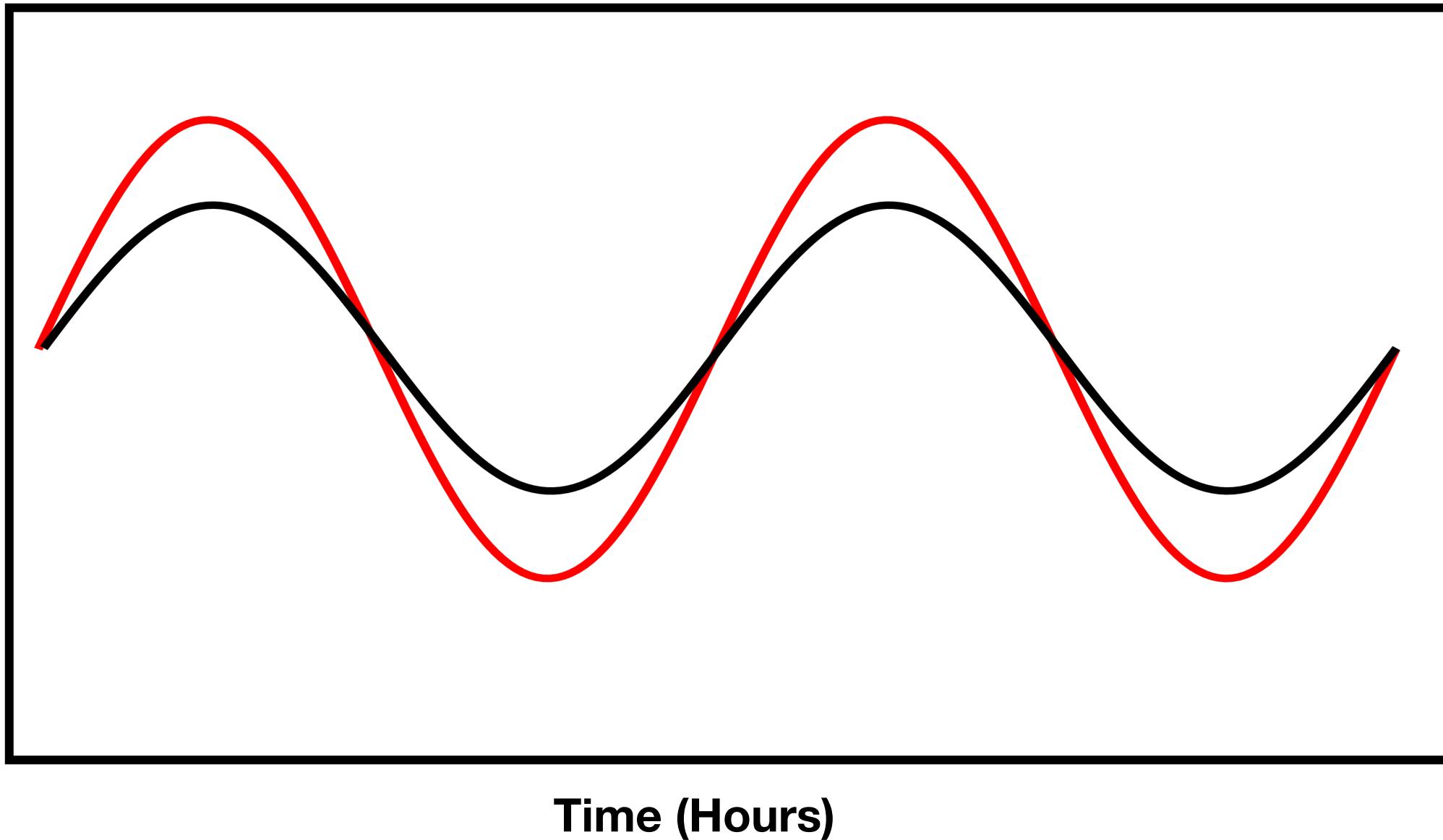
Research Question 1:
Are there detectable daily rhythms of cognitive function in everyday life?

Time (Hours)

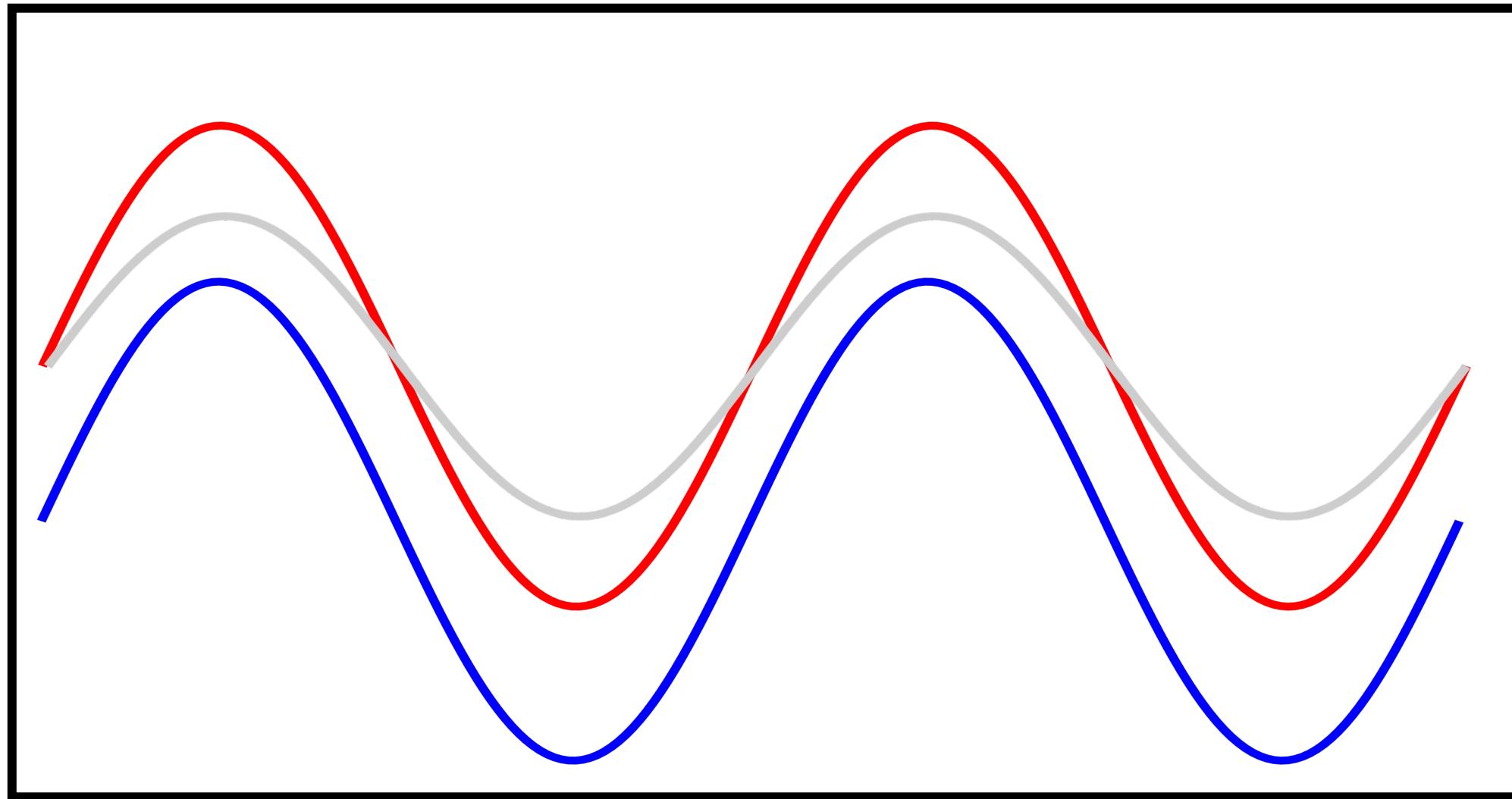
Individual Differences in Cognitive Variability



Individual Differences in Cognitive Variability

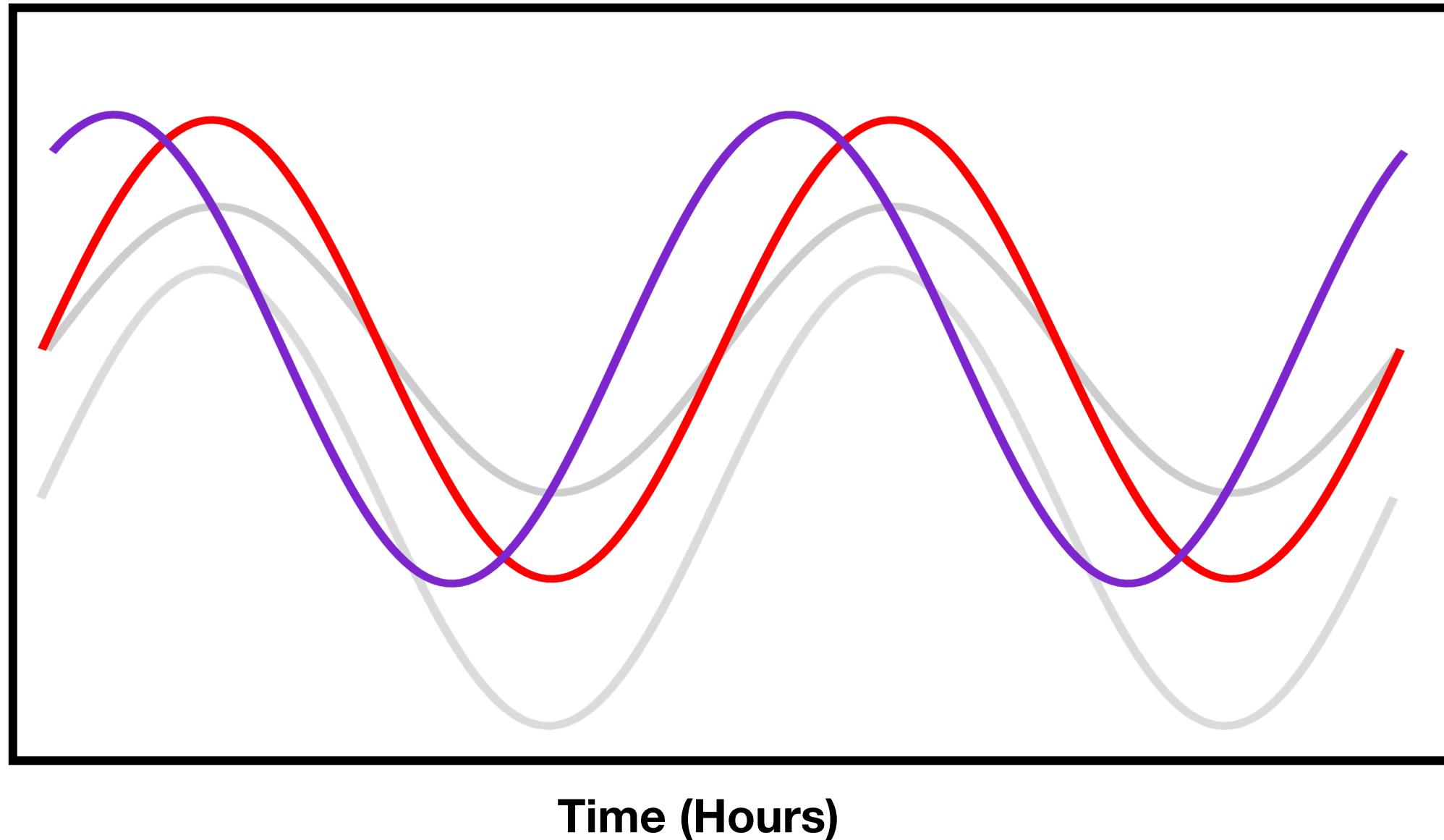


Individual Differences in Cognitive Variability



Time (Hours)

Individual Differences in Cognitive Variability



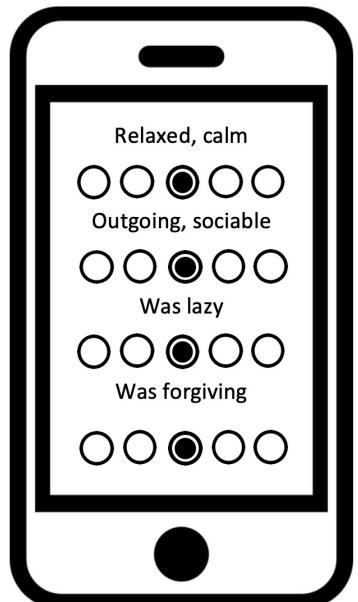
Individual Differences in Cognitive Variability

Research Question 2:
**Are there individual differences in
daily rhythms of cognitive function?**

Time (Hours)

Participants

Einstein Aging Study



**6x / day,
14 days**

$N = 316$
(15,356 surveys)

$M = 54.6$
 $SD = 15.8$

67.4% female
 $M_{age} = 77.0$
 $SD_{age} = 4.82$
 $M_{educ} = 15.0$
 $SD_{educ} = 3.53$

Dot Memory

(spatial working memory)

Color Dot

(working memory precision)

Color Shape Binding

(short-term memory binding)

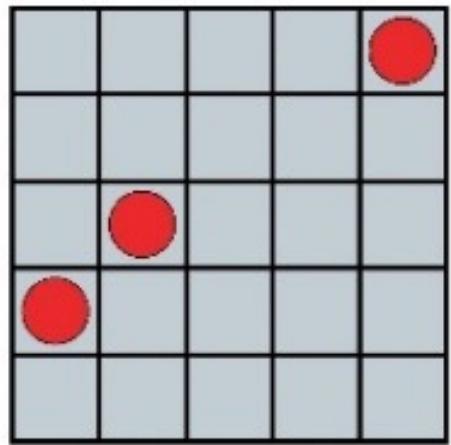
Symbol Search

(processing speed / visual attention)

Dot Memory

(spatial working memory)

Remember the dot locations!



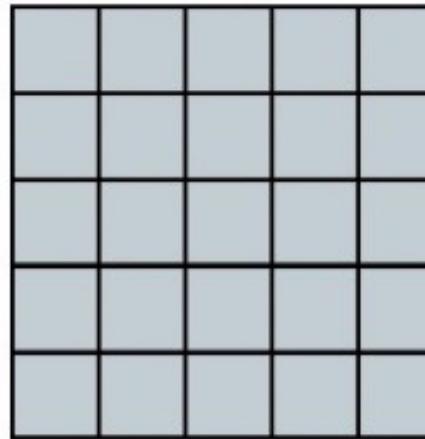
◀ ○ □

Touch the F's!

F E E E E
E E E E E
E E E E E
E E E E E
E E E E E
E E F E E
F E E E F
E F E F E

◀ ○ □

Where were the dots?



DONE

◀ ○ □

Four Performance Measures:

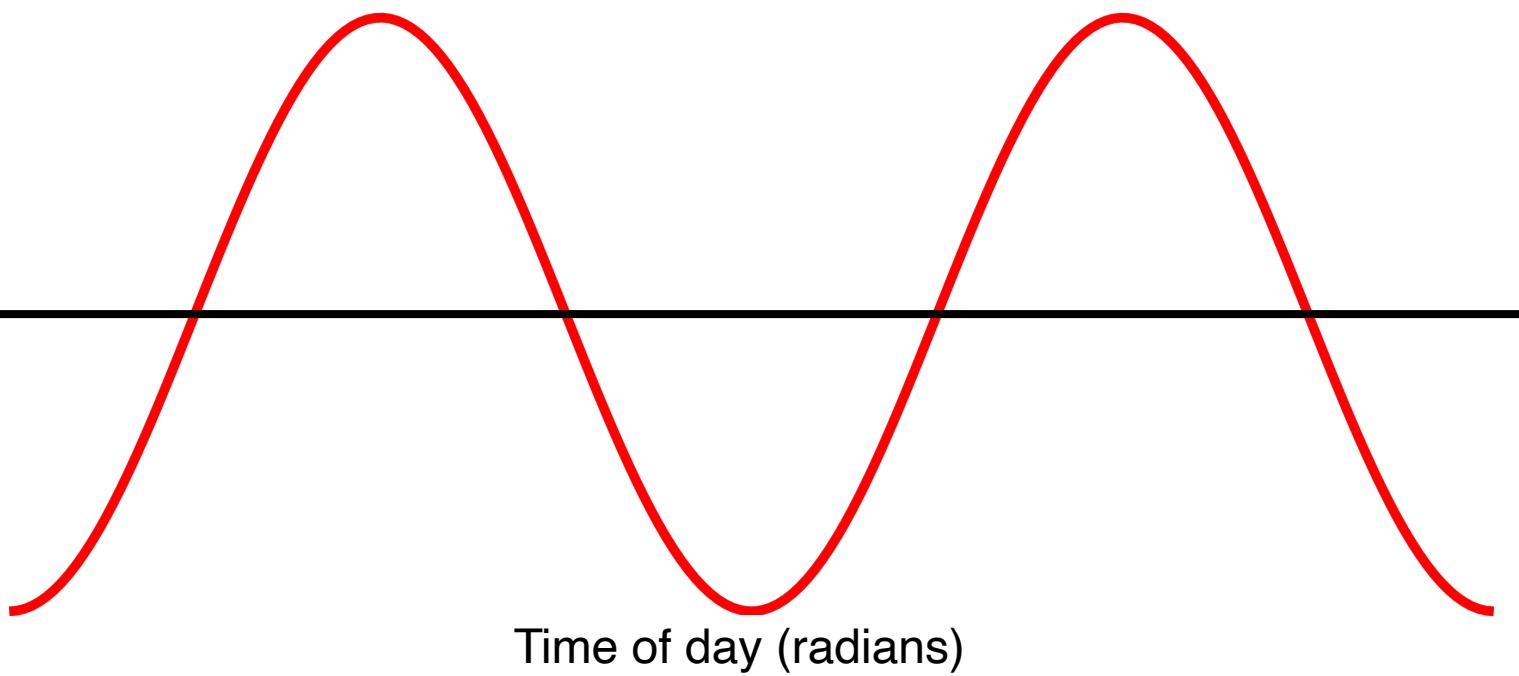
1. Mean Error
2. Sum of Error
3. Mean RT
4. Median RT

$$Cog_{it} = \beta_{0t} + \beta_{1t} * \sin(2\pi * time/9) + \beta_{2t} * \cos(2\pi * time/9) + error$$

Individual differences in levels of cognitive function

Not easily or obvious interpretable

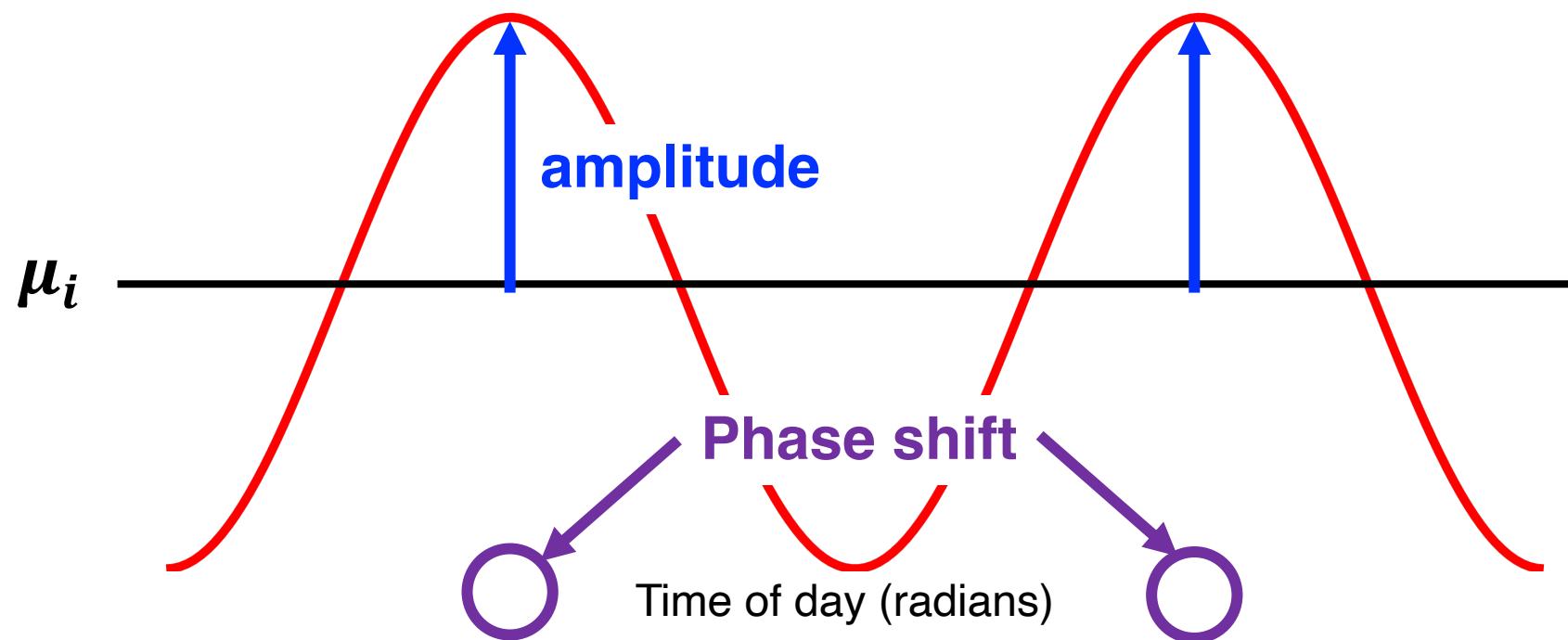
μ_i



$$Cog_{it} = \beta_{0t} + \beta_{1t} * \sin(2\pi * time/9) + \beta_{2t} * \cos(2\pi * time/9) + error$$

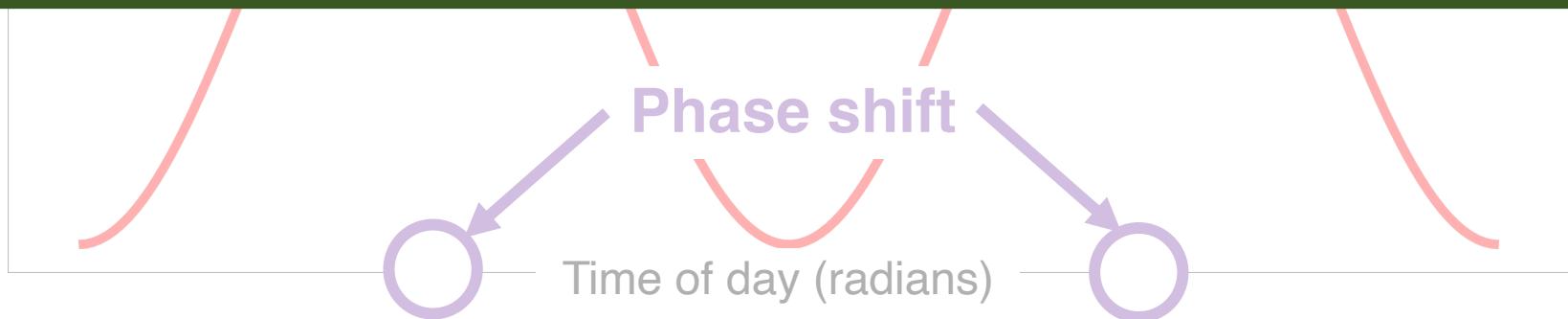
Amplitude
$\sqrt{\beta_{1t}^2 + \beta_{2t}^2}$

Phase Shift
$\begin{cases} \tan^{-1}(\beta_{1t}/\beta_{2t}) + \pi & IF \beta_{2t} < 0 \\ \tan^{-1}(\beta_{1t}/\beta_{2t}) & IF \beta_{2t} > 0 AND \beta_{1t} > 0 \\ \tan^{-1}(\beta_{1t}/\beta_{2t}) + 2\pi & IF \beta_{2t} > 0 AND \beta_{1t} < 0 \end{cases}$



$$CogScore_{it} = \beta_{0t} + \beta_{1t} * \sin(time) + \beta_{2t} * \cos(time) + error$$

Phase shift and amplitude let us capture individual differences in when peak performance occurs and differences in the degree of those peaks.

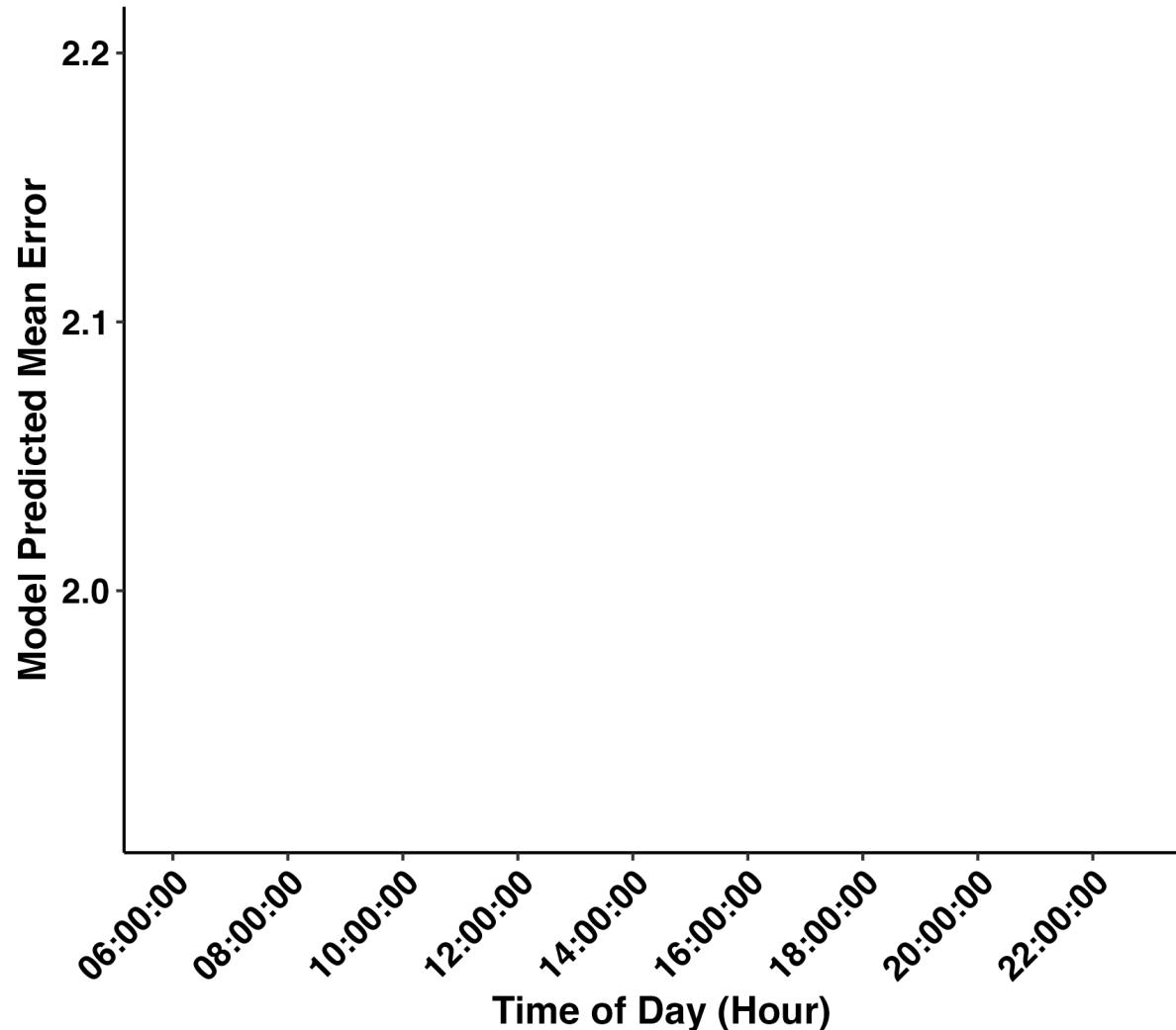


Q1: Detectable Daily Cycles of Cognitive Function

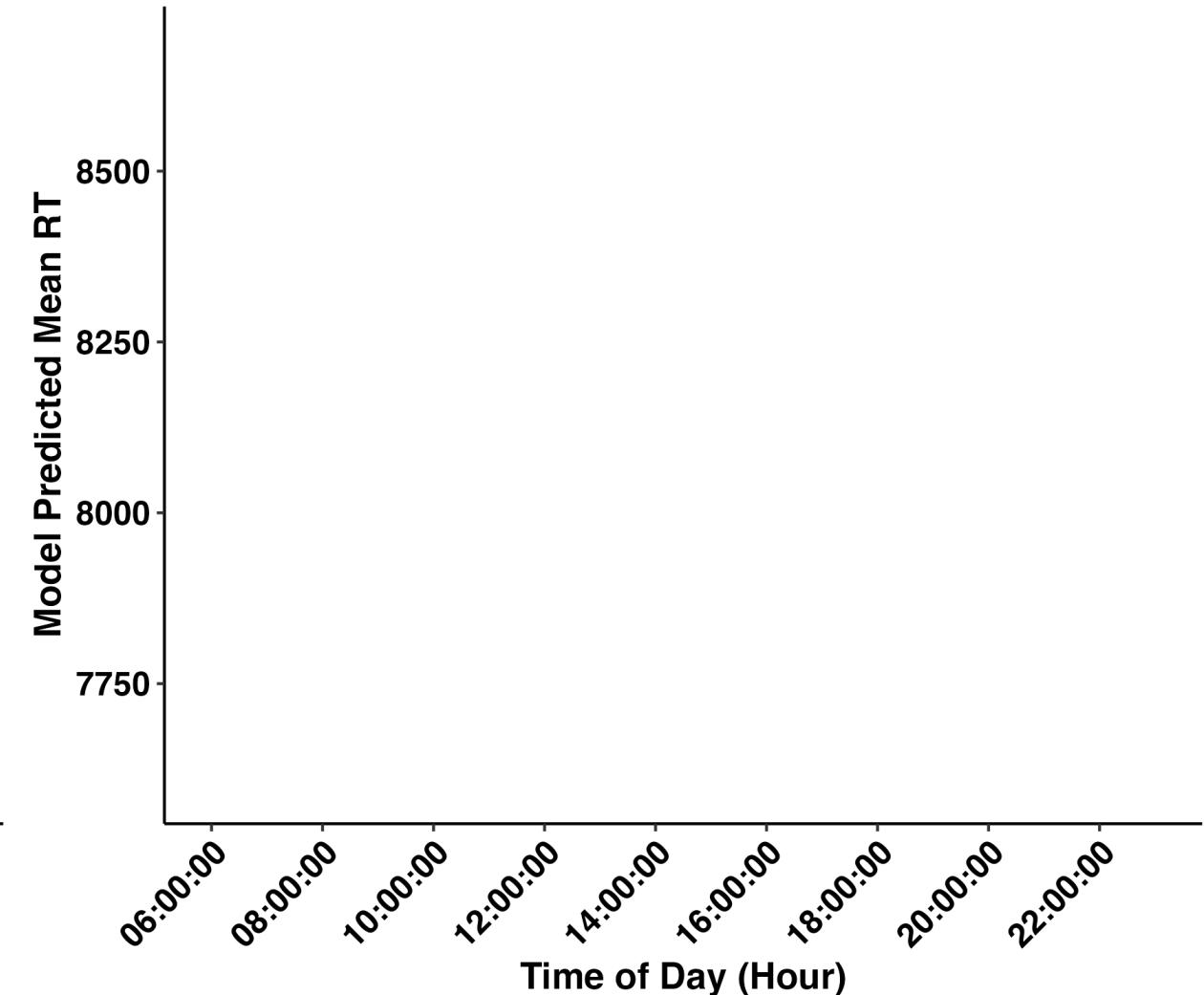
Dot Memory: Daily Rhythms

Cosinor Trends Within Day

Mean Error (Euclidean Distance)



Mean Response Time

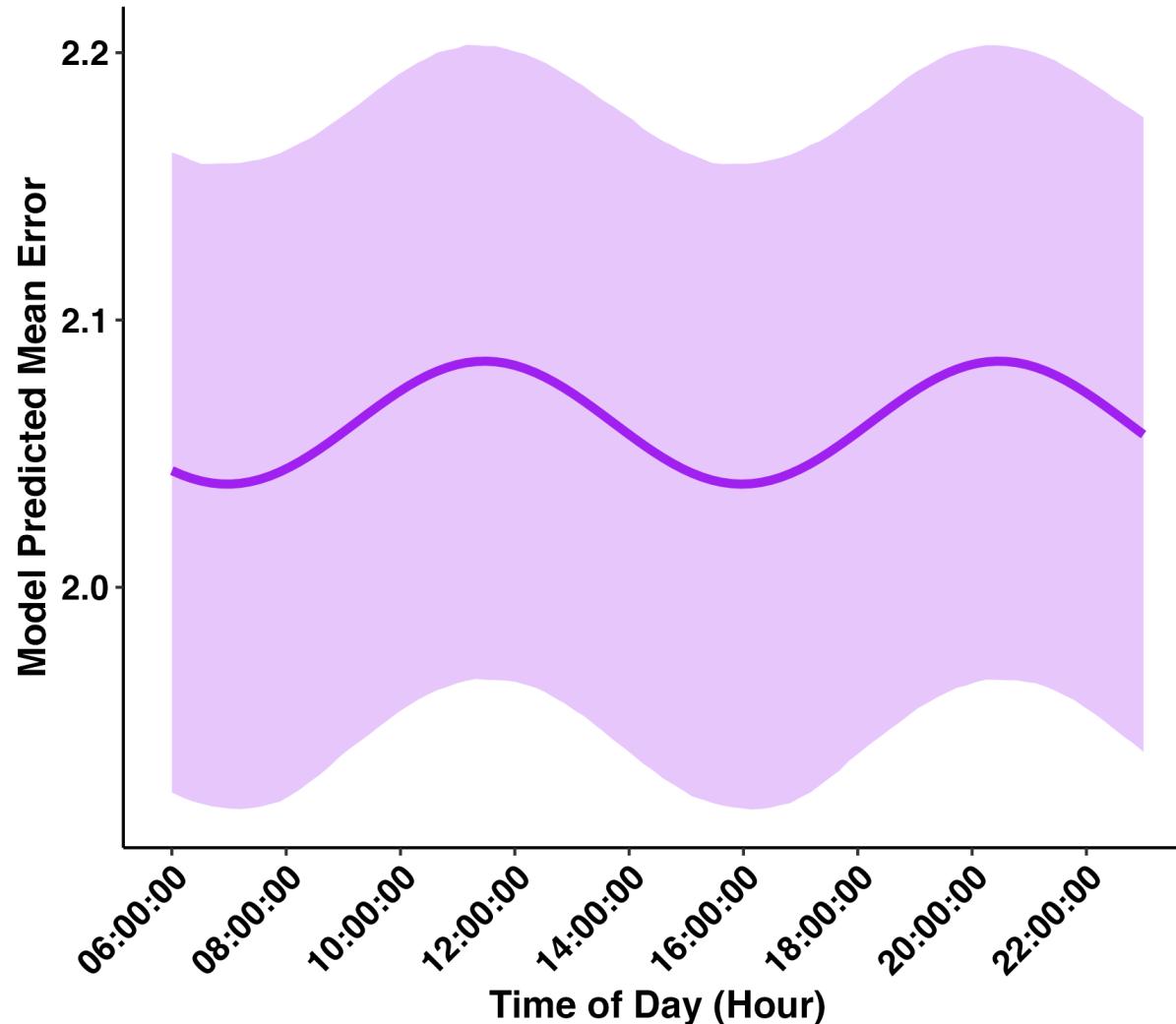


Q1: Detectable Daily Cycles of Cognitive Function

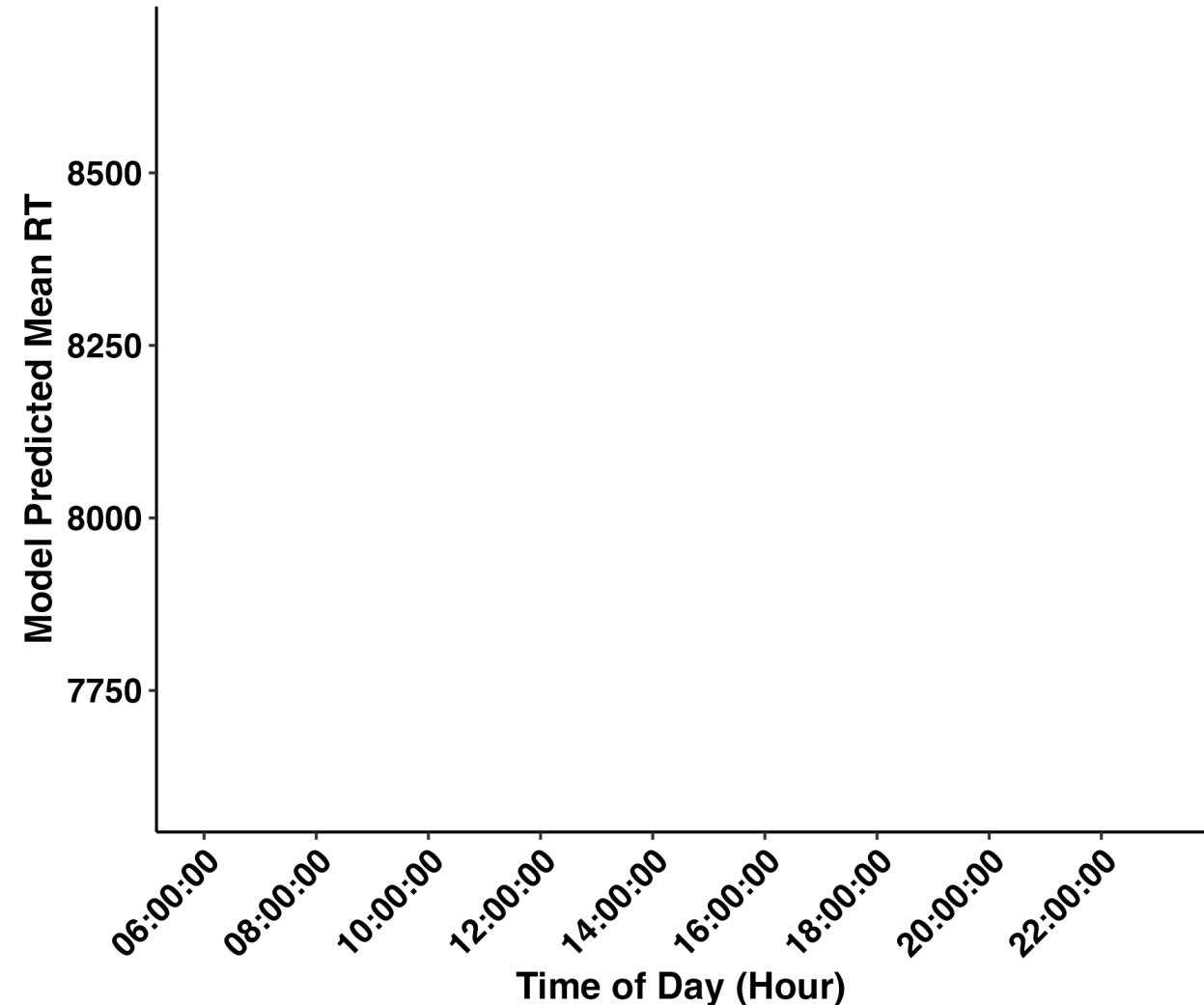
Dot Memory: Daily Rhythms

Cosinor Trends Within Day

Mean Error (Euclidean Distance)



Mean Response Time

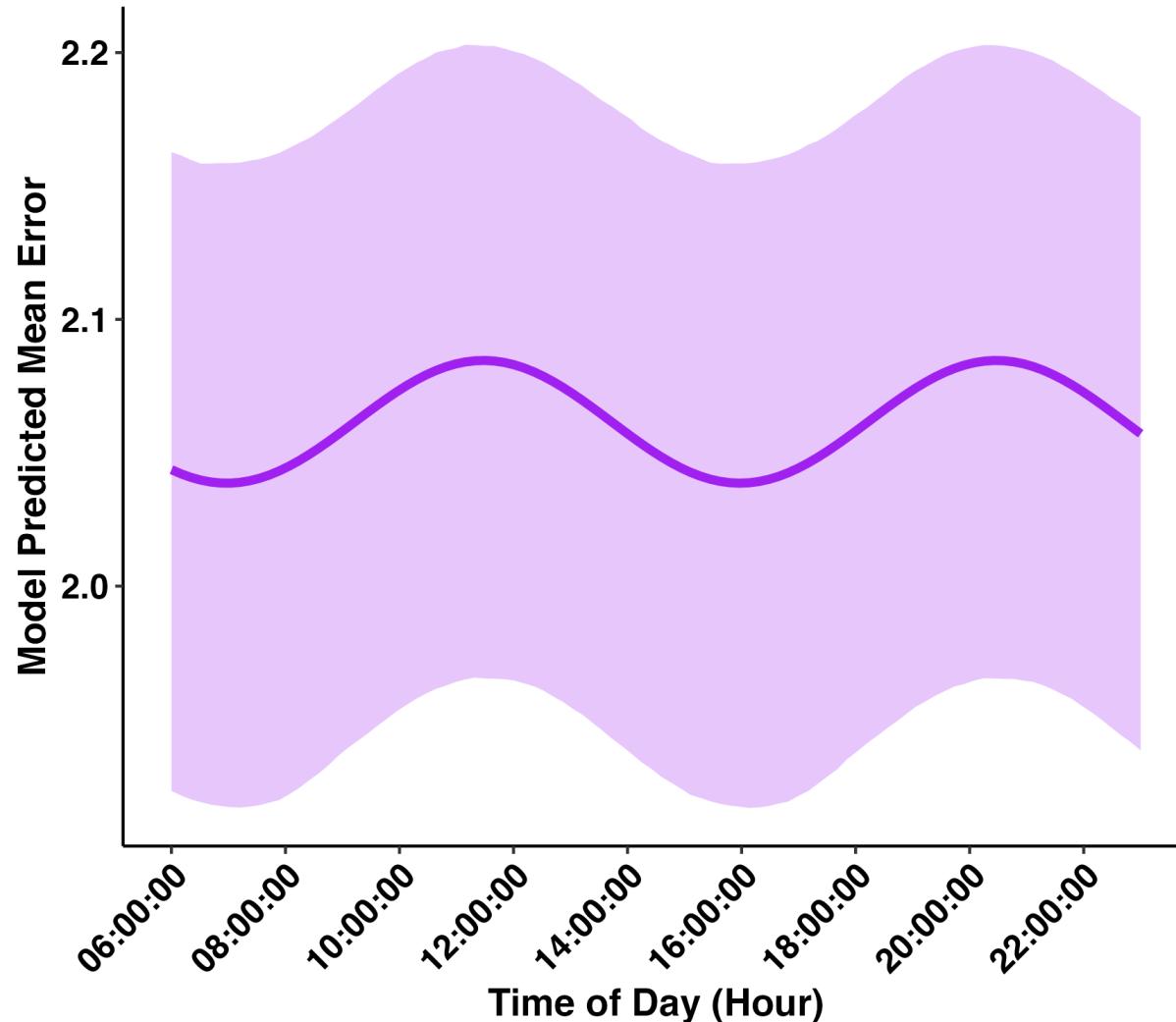


Q1: Detectable Daily Cycles of Cognitive Function

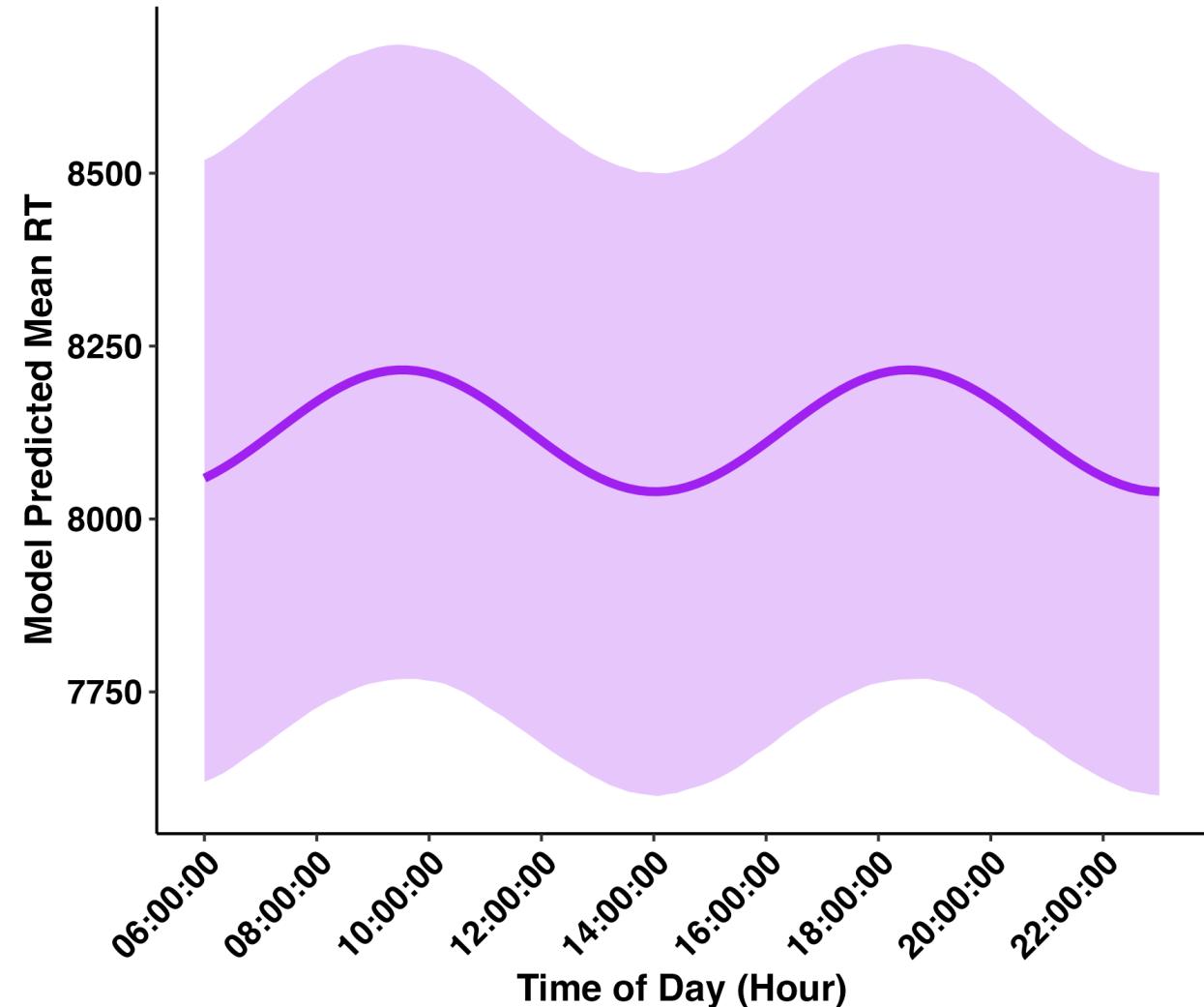
Dot Memory: Daily Rhythms

Cosinor Trends Within Day

Mean Error (Euclidean Distance)



Mean Response Time



Q1: Detectable Daily Cycles of Cognitive Function

Dot Memory: Daily Rhythms

Cosinor Trends Within Day

On average, there are small rhythms of spatial working memory.

Model Predicted Mean Error

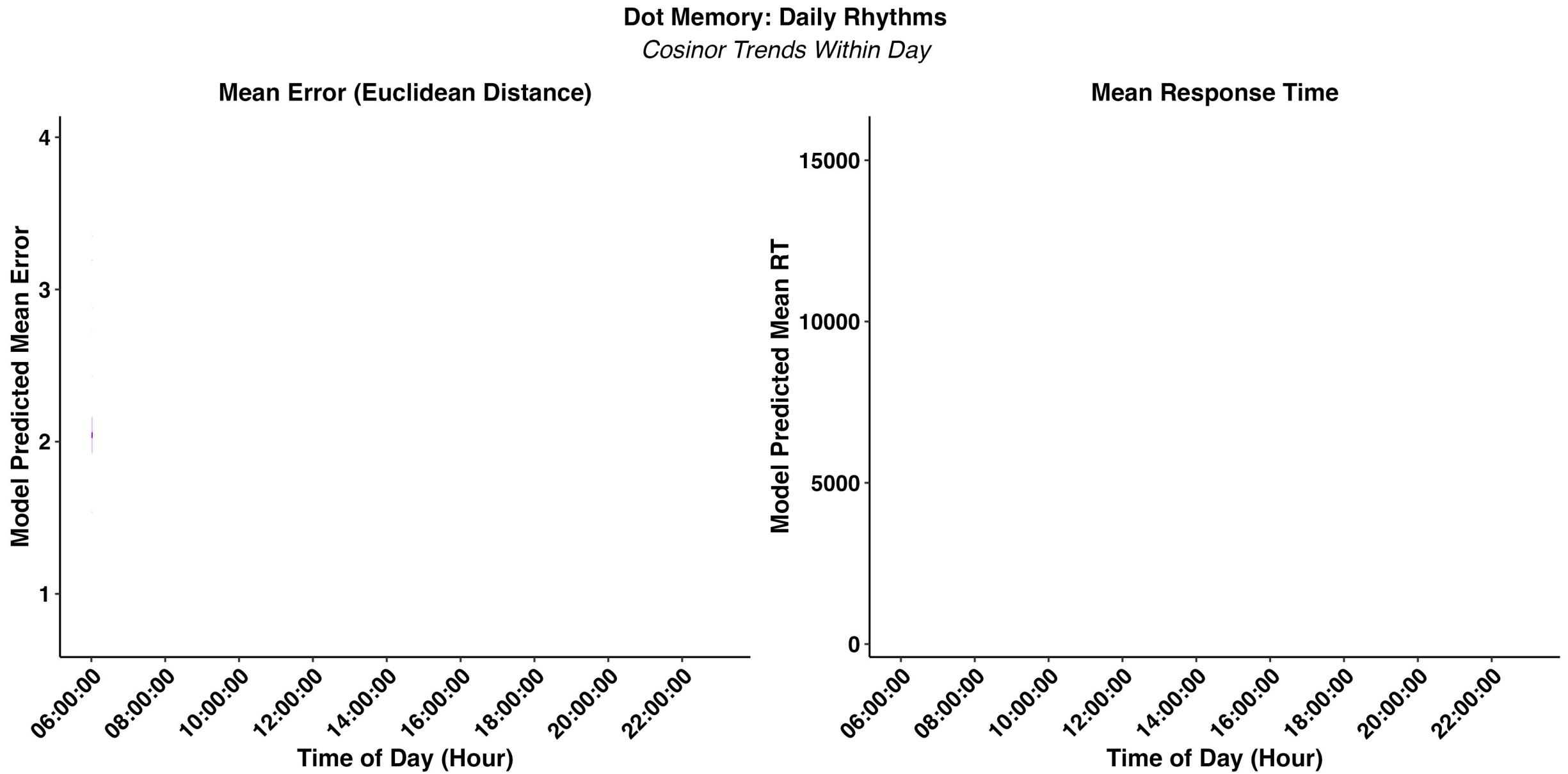
2.2

2.1

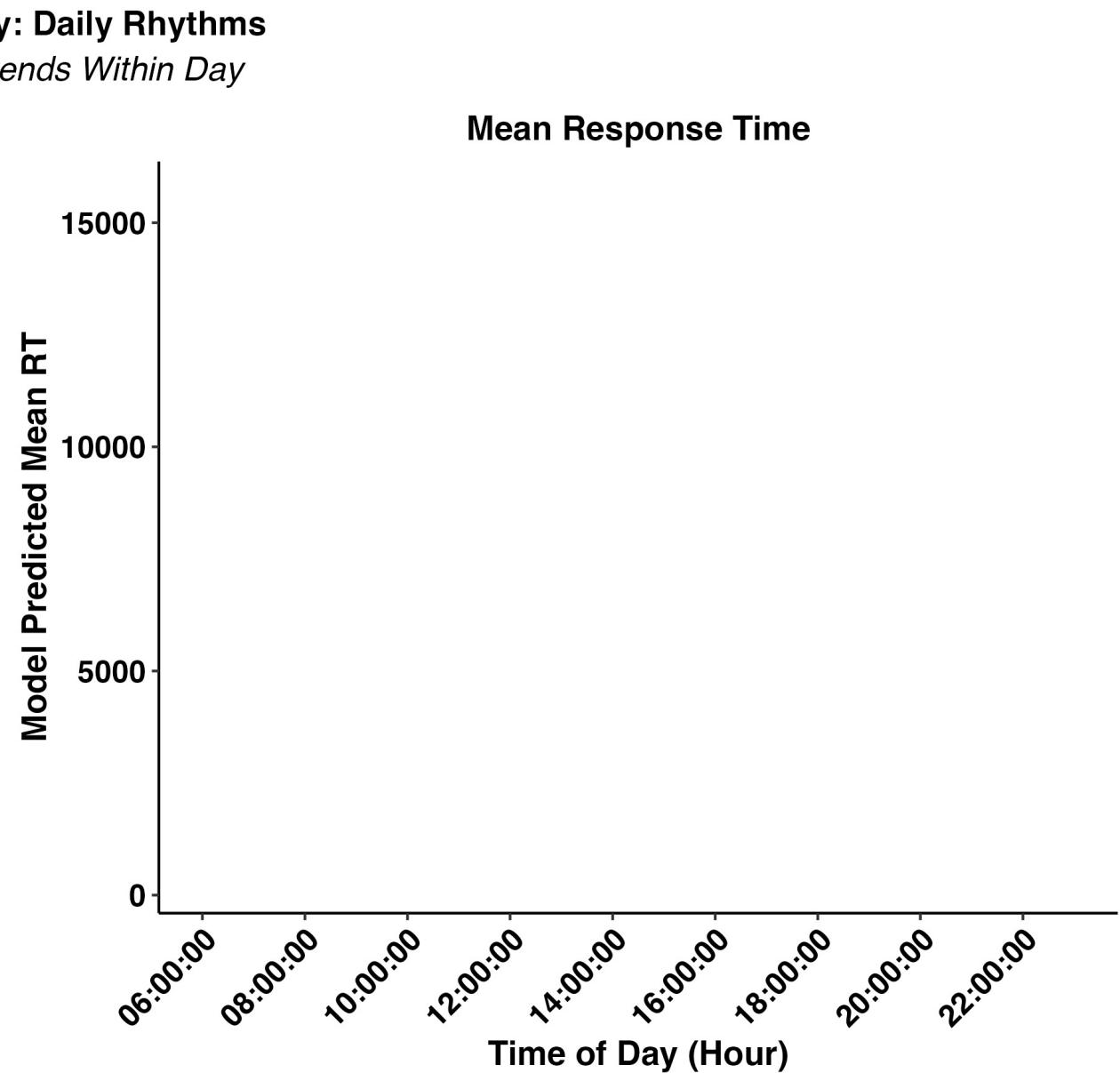
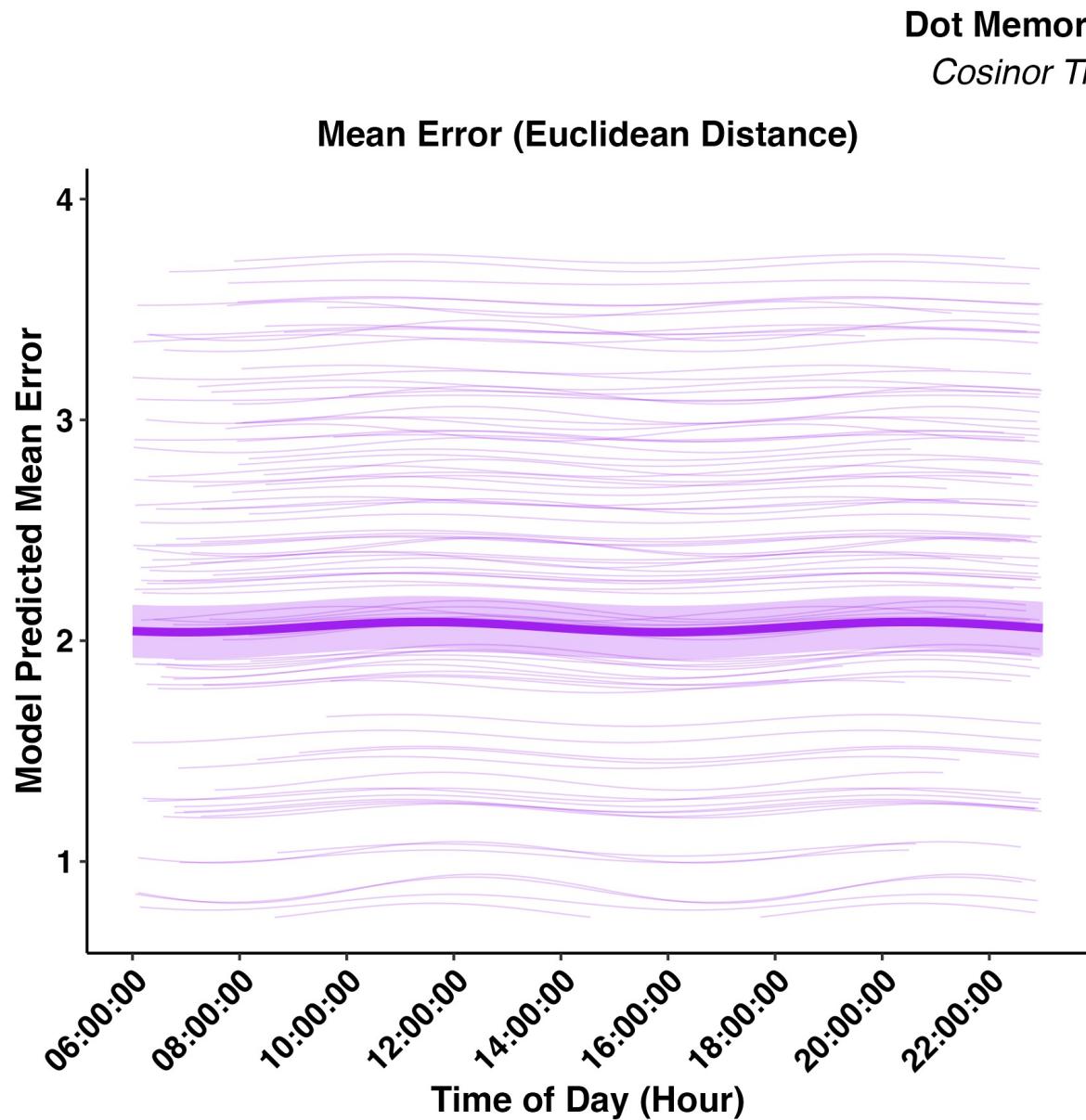
2.0



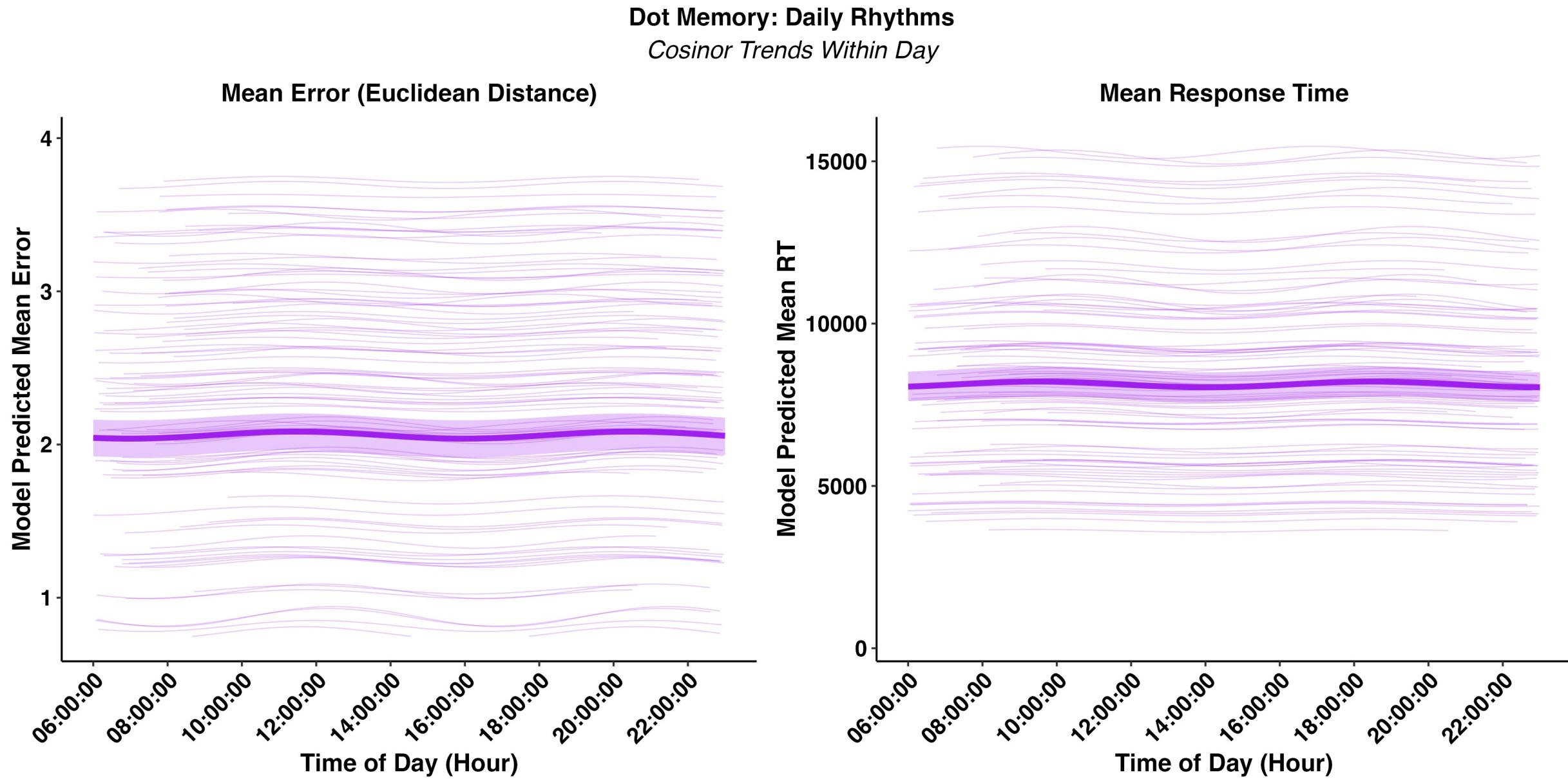
Q2: Individual Differences in Daily Cycles of Cognitive Function



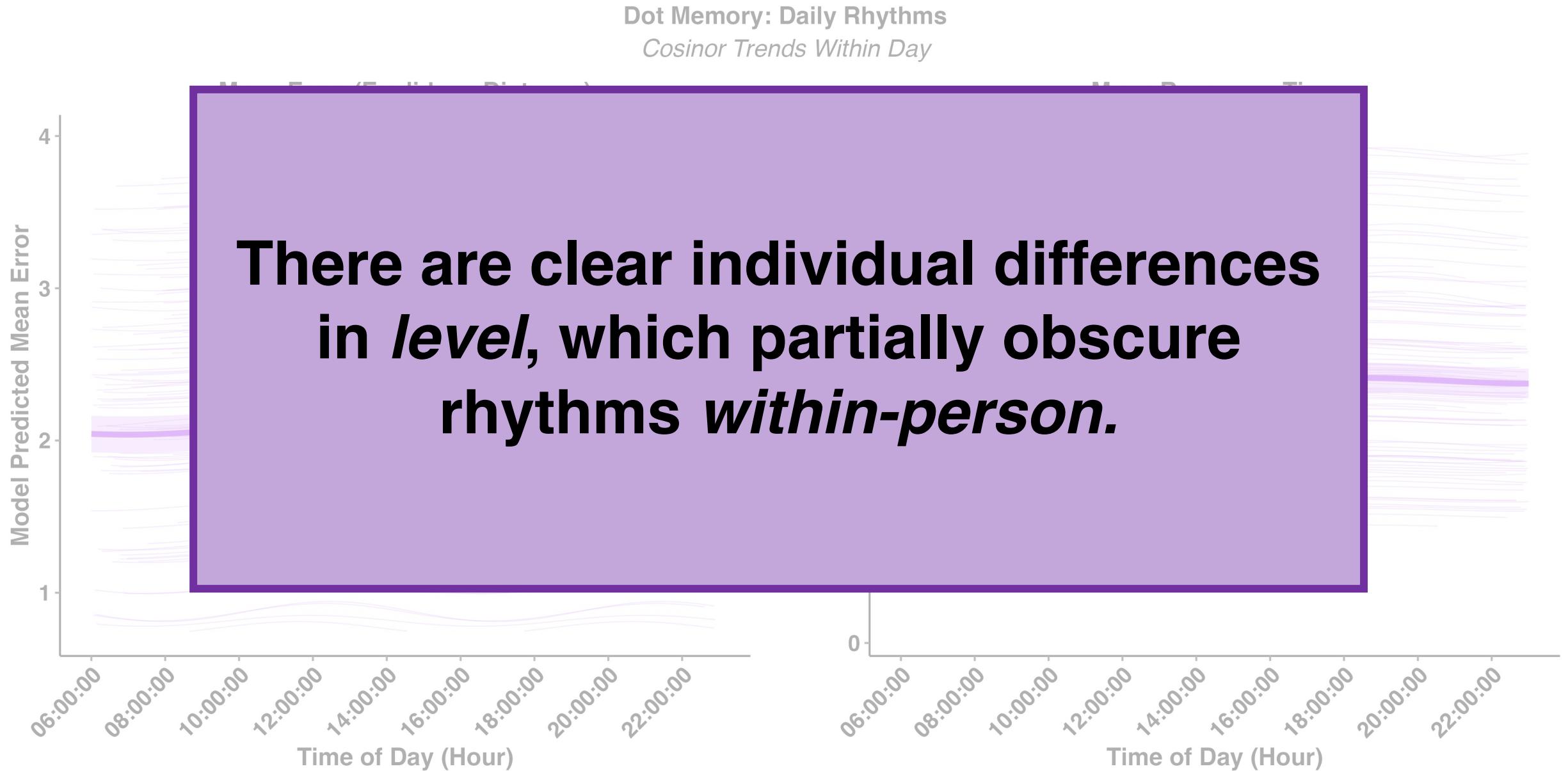
Q2: Individual Differences in Daily Cycles of Cognitive Function



Q2: Individual Differences in Daily Cycles of Cognitive Function



Q2: Individual Differences in Daily Cycles of Cognitive Function



Q2: Individual Differences in Daily Cycles of Cognitive Function

Dot Memory: Daily Rhythms

Cosinor Trends Within Day

Mean Error (Euclidean Distance)

Model Predicted Mean Error

0.04
0.00
-0.04

06:00:00 08:00:00 10:00:00 12:00:00 14:00:00 16:00:00 18:00:00 20:00:00 22:00:00

Time of Day (Hour)

Mean Response Time

Model Predicted Mean RT

200
0
-200

06:00:00 08:00:00 10:00:00 12:00:00 14:00:00 16:00:00 18:00:00 20:00:00 22:00:00

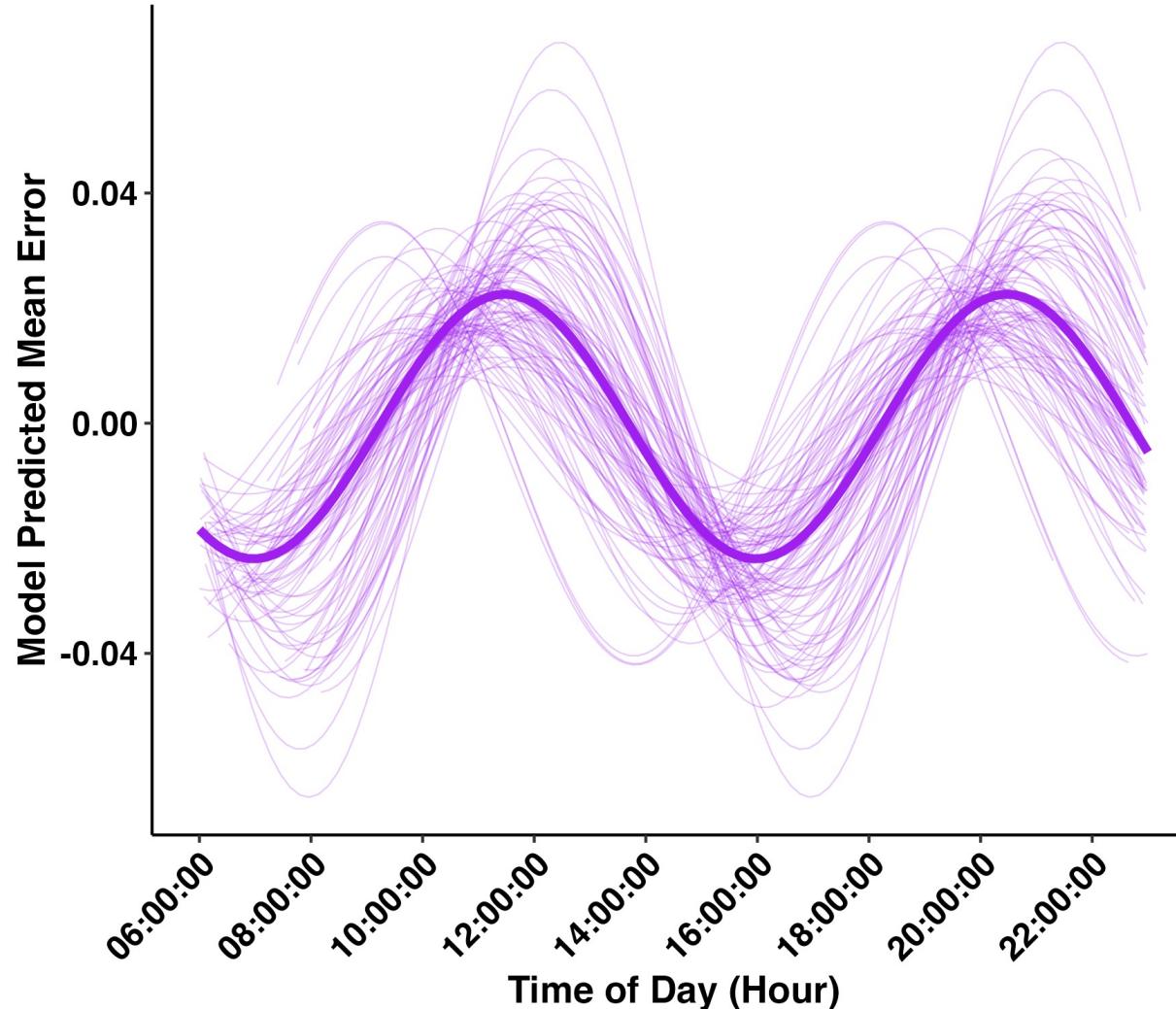
Time of Day (Hour)

Q2: Individual Differences in Daily Cycles of Cognitive Function

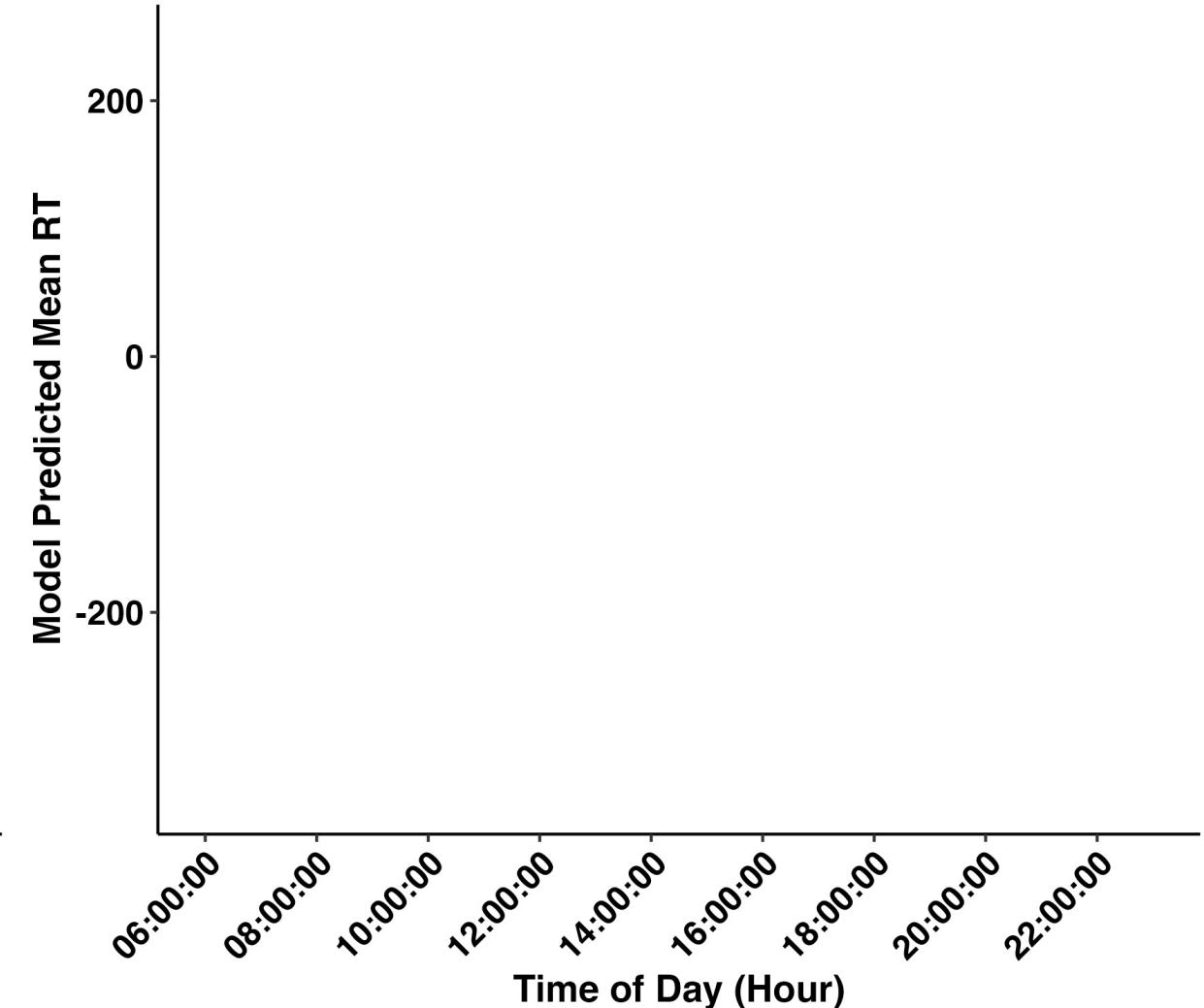
Dot Memory: Daily Rhythms

Cosinor Trends Within Day

Mean Error (Euclidean Distance)



Mean Response Time

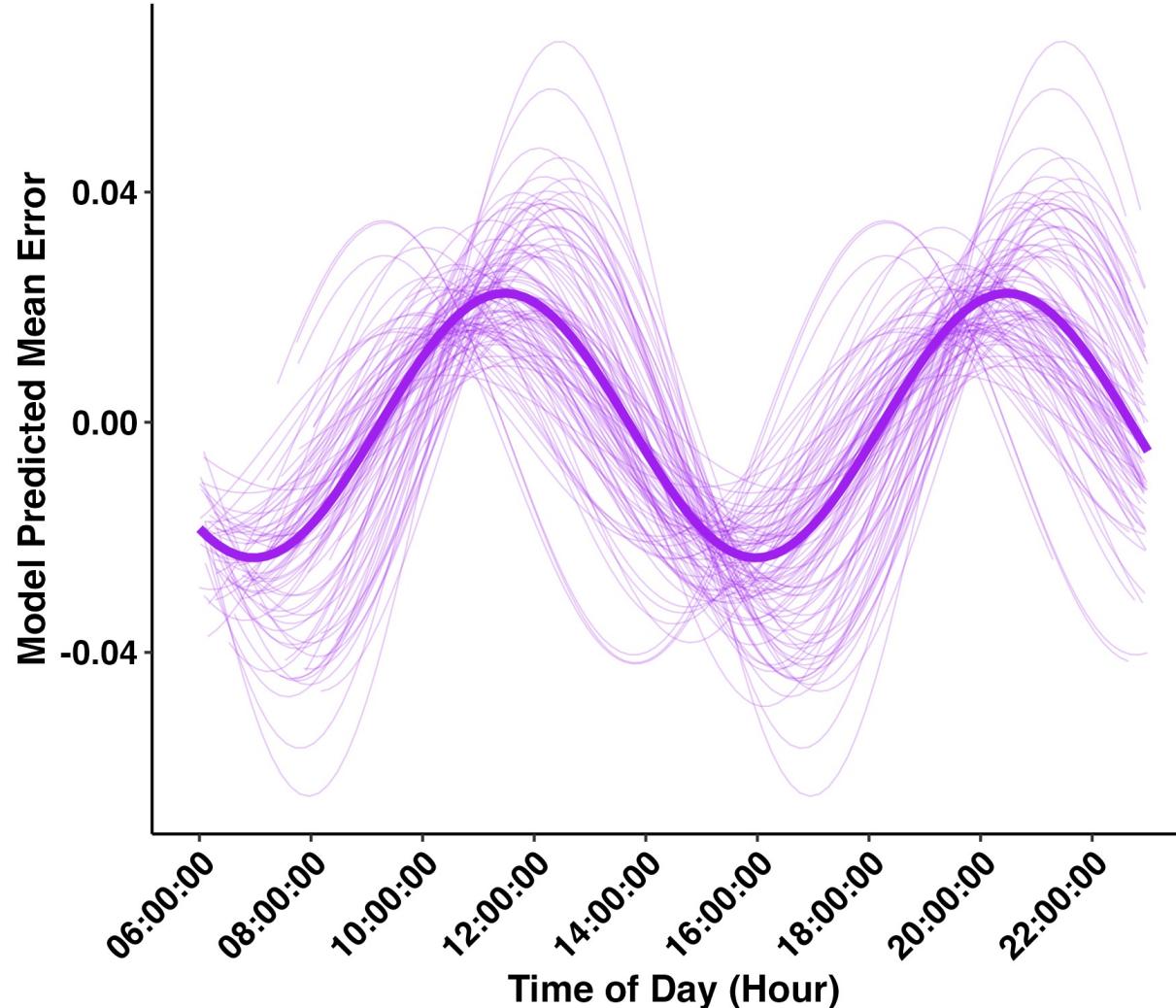


Q2: Individual Differences in Daily Cycles of Cognitive Function

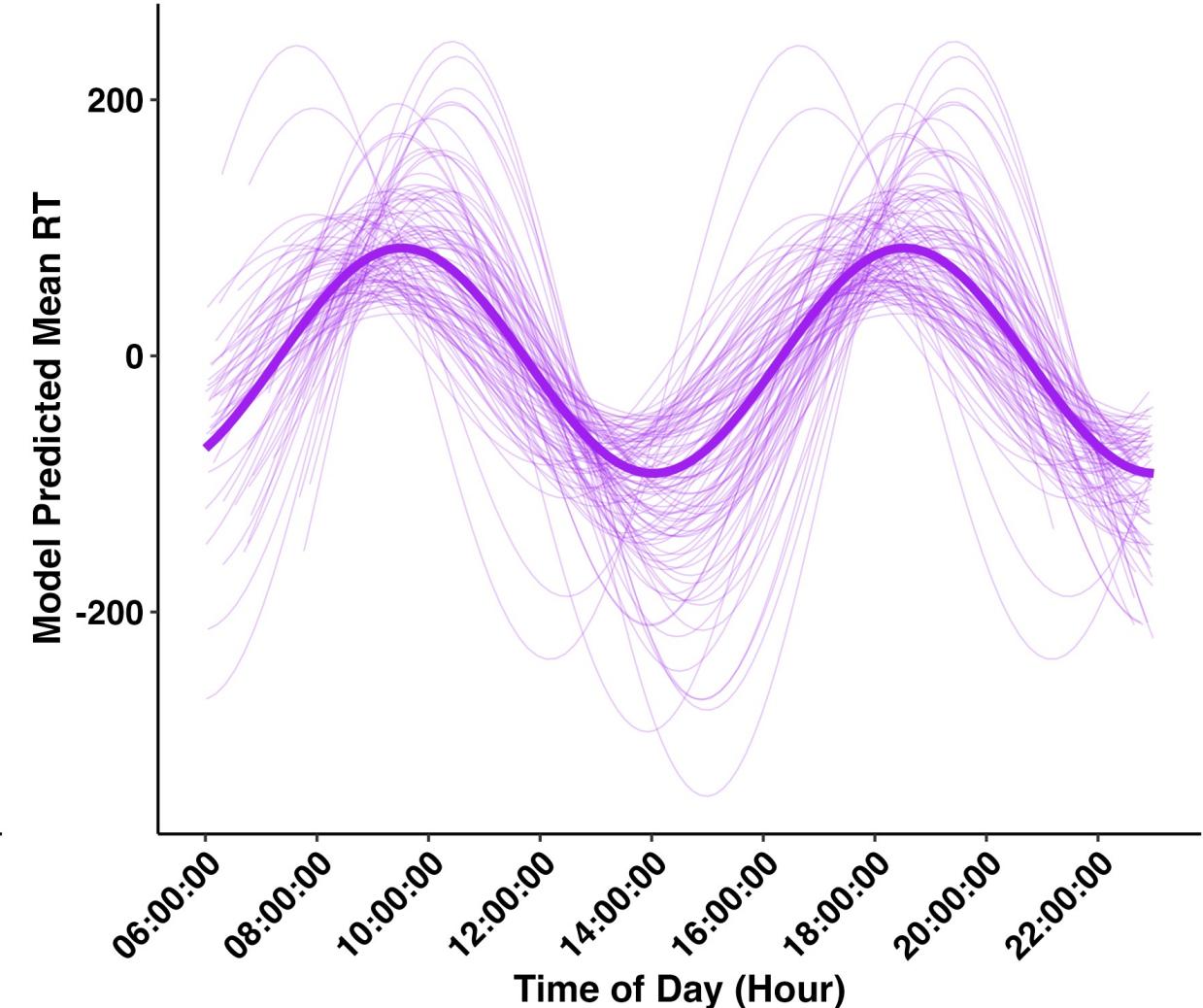
Dot Memory: Daily Rhythms

Cosinor Trends Within Day

Mean Error (Euclidean Distance)



Mean Response Time



Q2: Individual Differences in Daily Cycles of Cognitive Function

Dot Memory: Daily Rhythms

Cosinor Trends Within Day

Within-person, there are individual differences in when dips in performance occur (phase shift) and how extreme they are (amplitude).

Model Predicted Mean Error

0.04

0.00

-0.04

06:00:00

08:00:00

10:00:00

12:00:00

14:00:00

16:00:00

18:00:00

20:00:00

22:00:00

Time of Day (Hour)

06:00:00

08:00:00

10:00:00

12:00:00

14:00:00

16:00:00

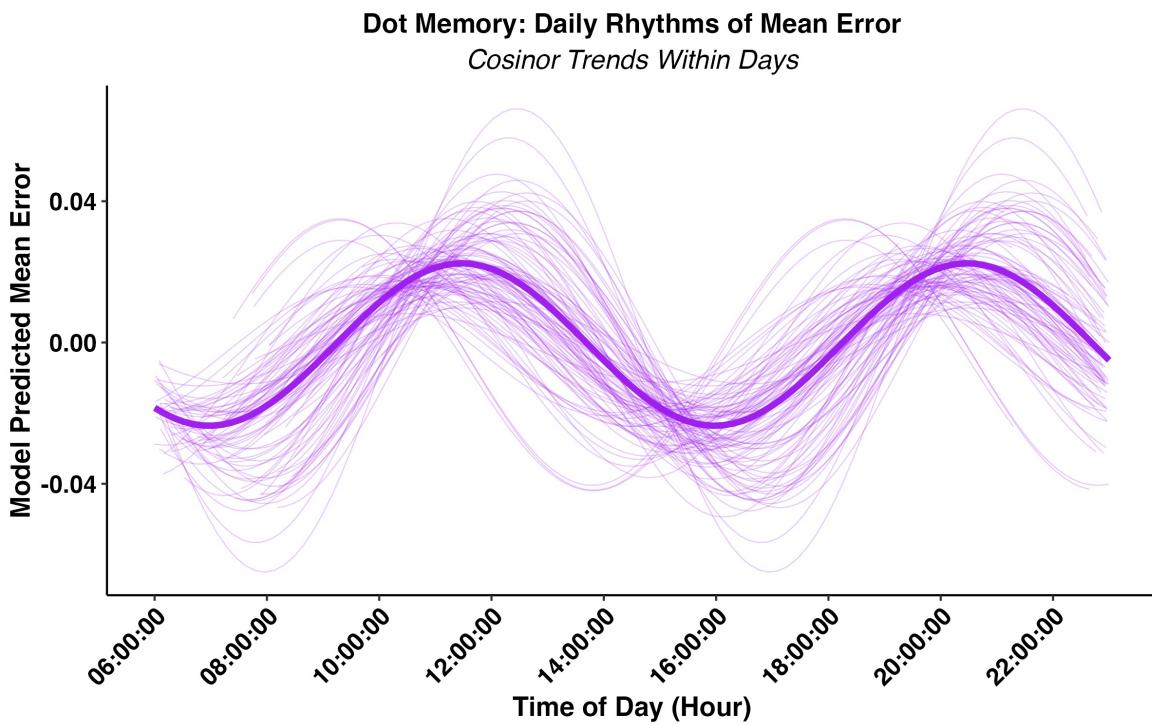
18:00:00

20:00:00

22:00:00

Time of Day (Hour)

Summary

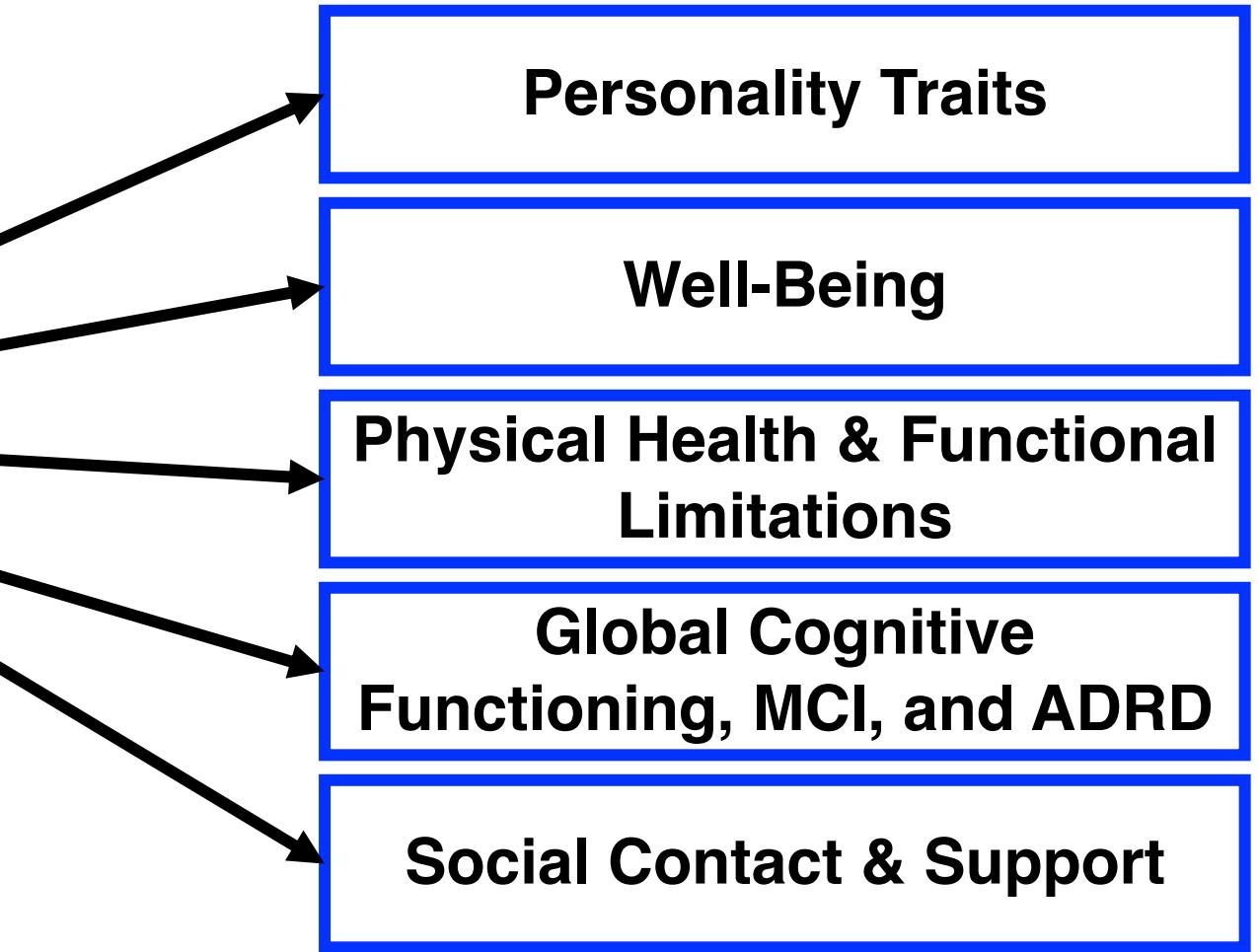
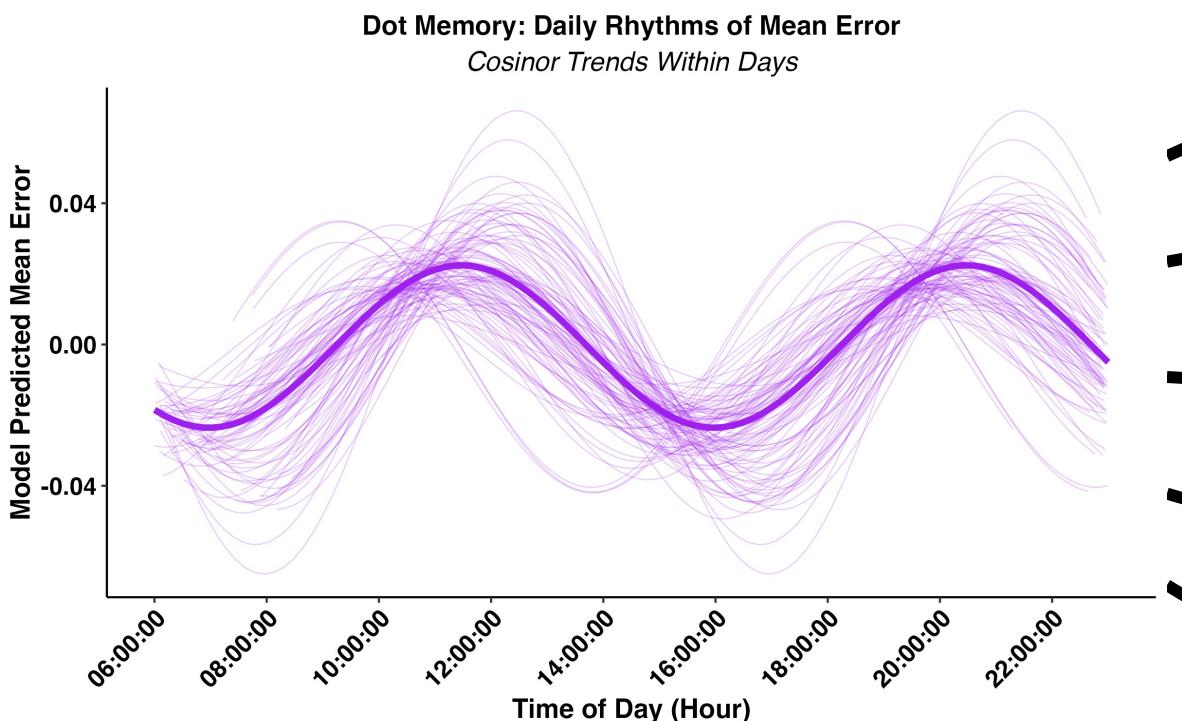


There are detectable daily rhythms in cognitive function and individual differences in those.

But how *valid* are they?

Next Steps

What are individual differences in cognitive rhythms associated with?



Thank You!

Materials & Contact



<https://osf.io/rkunv>



<https://osf.io/z6tkm>



edbeck@ucdavis.edu



@EmorieBeck

Collaborators

Zoë Hawks

Eileen Graham

Dan Mroczek

Stacey Scott

Orfeu Buxton

The What is Personality? Lab



UCDAVIS
UNIVERSITY OF CALIFORNIA

$$Cog_{ijk} = \beta_{0ij} + \beta_{1ij} * TimeDayLin_{ijk} + \beta_{2ij} * MeasOcc_{ijk} + \\ \beta_{3ij} * \sin(radTime_{ijk}) + \beta_{4ij} * \cos(radTime_{ijk}) + \epsilon_{ijk}$$

Day Level

$$\beta_{0ij} = \gamma_{00i} + u_{0ij}$$

$$\beta_{1ij} = \gamma_{10i}$$

$$\beta_{2ij} = \gamma_{20i}$$

$$\beta_{3ij} = \gamma_{30i}$$

$$\beta_{4ij} = \gamma_{40i}$$

Person Level

$$\gamma_{00i} = \pi_{000} + r_{00i} \quad (\text{person } i \text{ average of cognitive function})$$

$$\gamma_{10i} = \pi_{100} + r_{10i} \quad (\text{person } i \text{ within-day slope})$$

$$\gamma_{20i} = \pi_{200} + r_{20i} \quad (\text{person } i \text{ across beep slope})$$

$$\gamma_{30i} = \pi_{300} + r_{30i} \quad (\text{person } i \text{ sine curve})$$

$$\gamma_{40i} = \pi_{400} + r_{40i} \quad (\text{person } i \text{ cos curve})$$