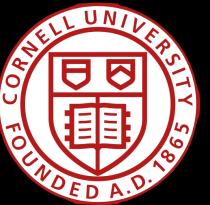


# TOWARDS CIRCADIAN COMPUTING: "EARLY TO BED AND EARLY TO RISE" MAKES SOME OF US UNHEALTHY AND SLEEP DEPRIVED

SAEED ABDULLAH, MARK MATTHEWS, ELIZABETH L.  
MURNANE, GERI GAY, TANZEEM CHOUDHURY



Cornell University

 Search

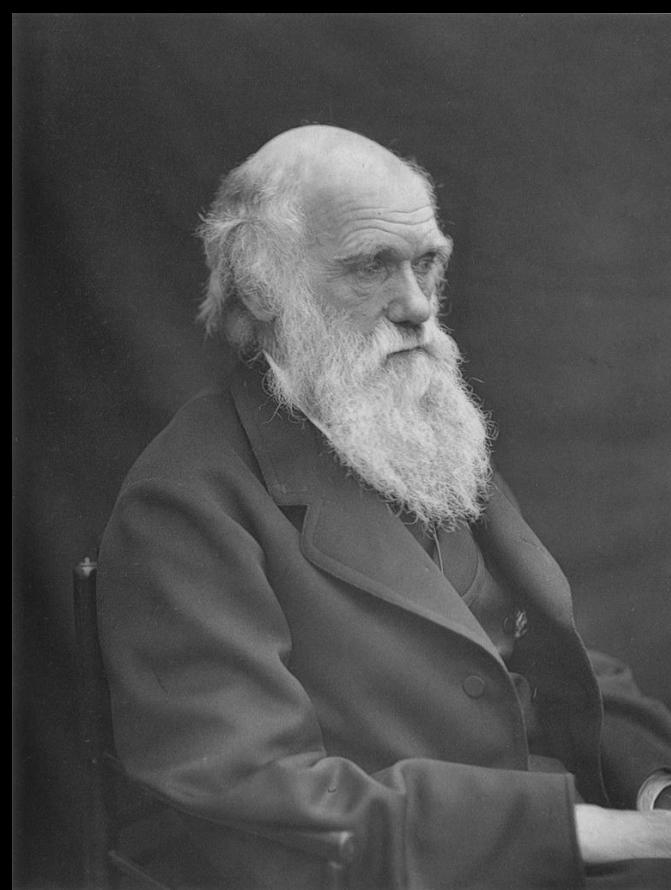
# Be More Productive by Waking Up Early

MOST OF US **CAN'T** AND  
**SHOULDN'T** MAINTAIN "EARLY TO  
BED AND EARLY TO RISE" LIFESTYLE

# RHYTHM IN LEAF MOVEMENT



- De Mairan
- 1729



- Charles Darwin
- 1880

# RHYTHM IN LEAF MOVEMENT



4/20/01 3:14 PM

BIOLOGICAL CLOCKS HAVE BEEN  
FOUND IN PLANTS, ANIMALS,  
INSECTS AND BACTERIA

WHAT ABOUT HUMANS?

# TIME-FREE ENVIRONMENT

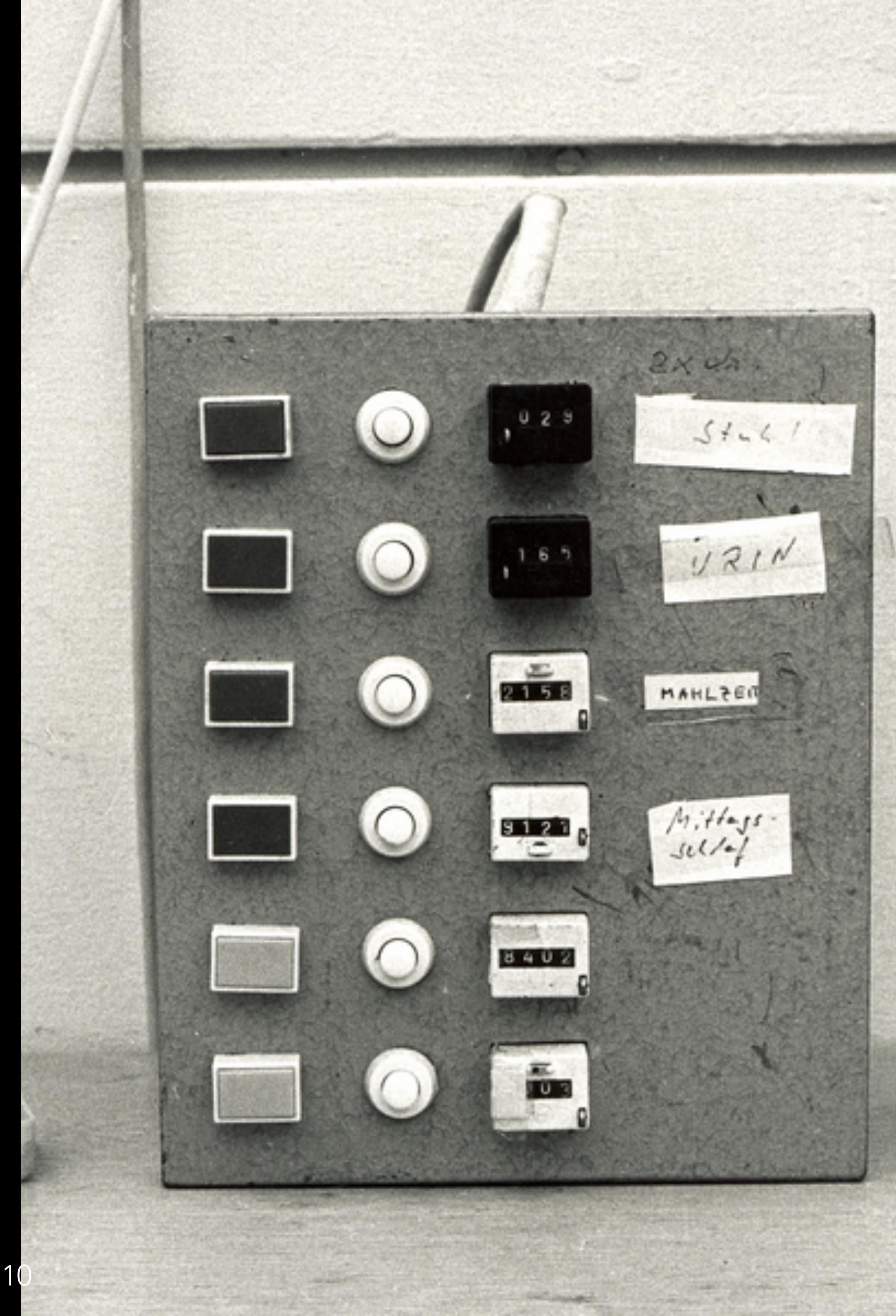
- Converted World War II bunkers
- Sound proof
- Shielded against vibration and electromagnetic field
- Complete social isolation

# TIME-FREE ENVIRONMENT



# TIME-FREE ENVIRONMENT

- Movement and activity
- Metabolism data from urine sample
- Temperature
- Sleep and mood journal



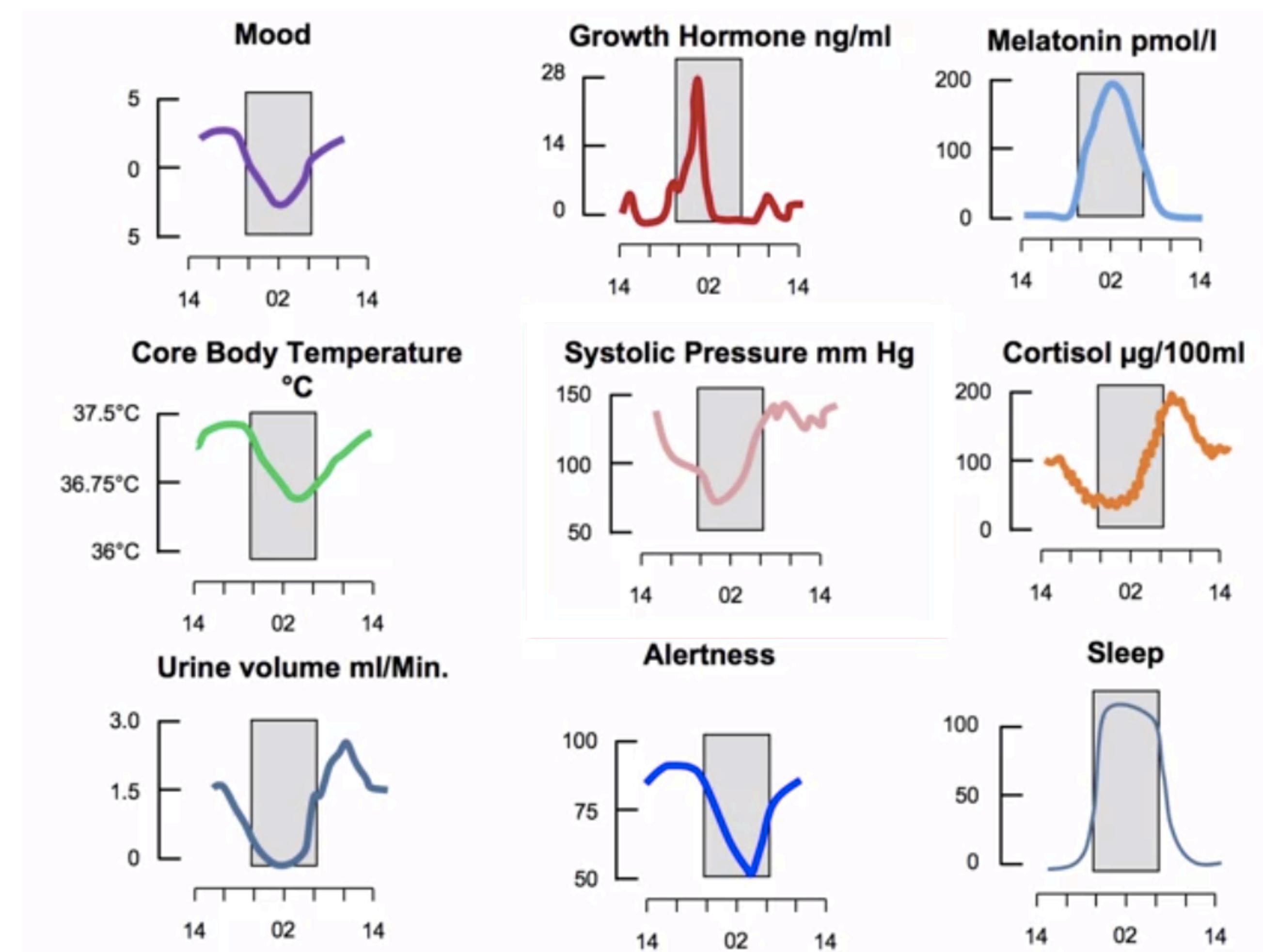
# TIME-FREE ENVIRONMENT



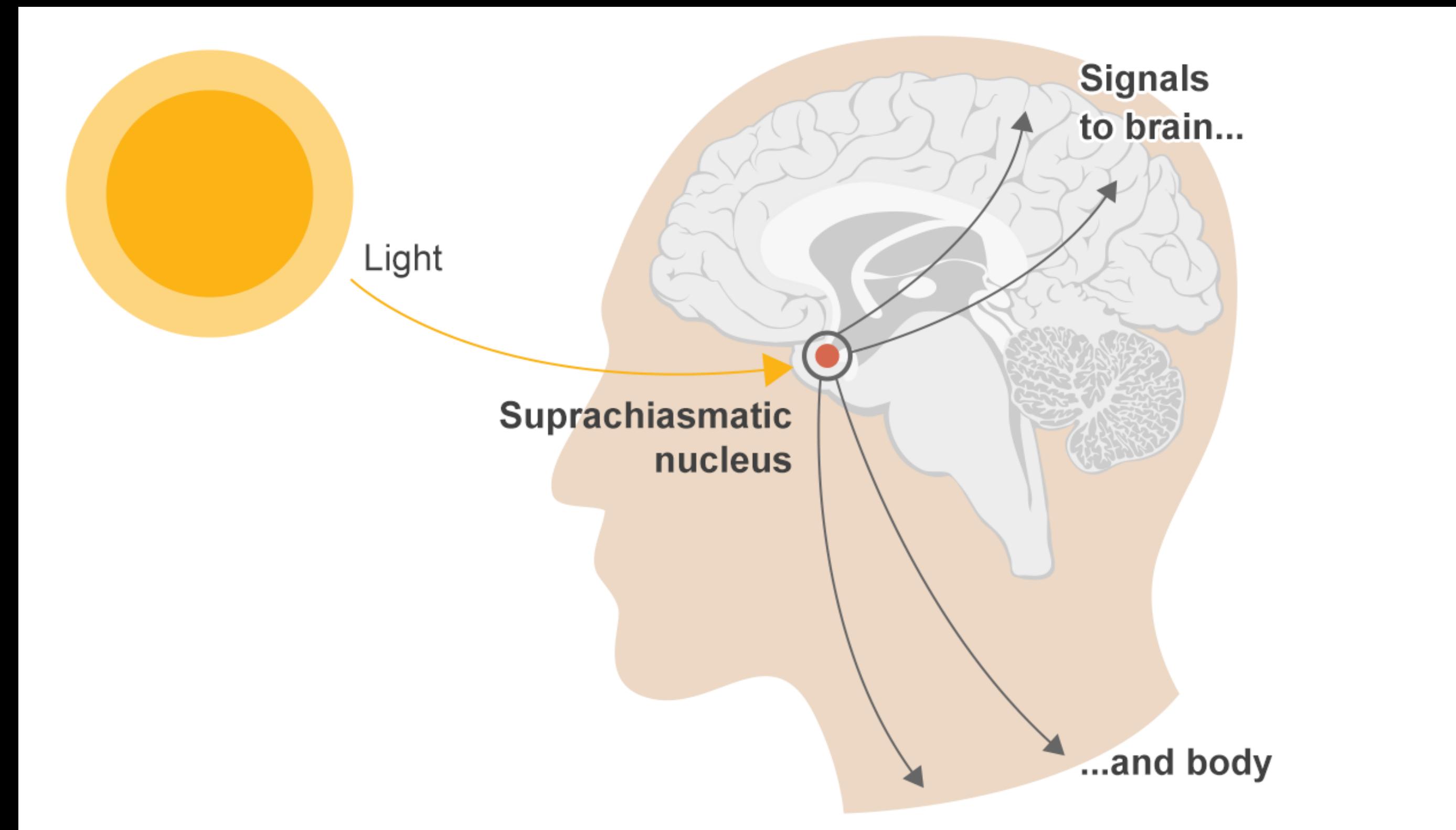
CIRCA: ABOUT, DIEM: A DAY

**CIRCADIAN RHYTHM:**  
BIOLOGICAL PROCESSES FOLLOWING  
ROUGHLY 24-HOUR PERIOD

# ALMOST EVERY NEUROBEHAVIORAL PROCESS REFLECTS CIRCADIAN RHYTHMS

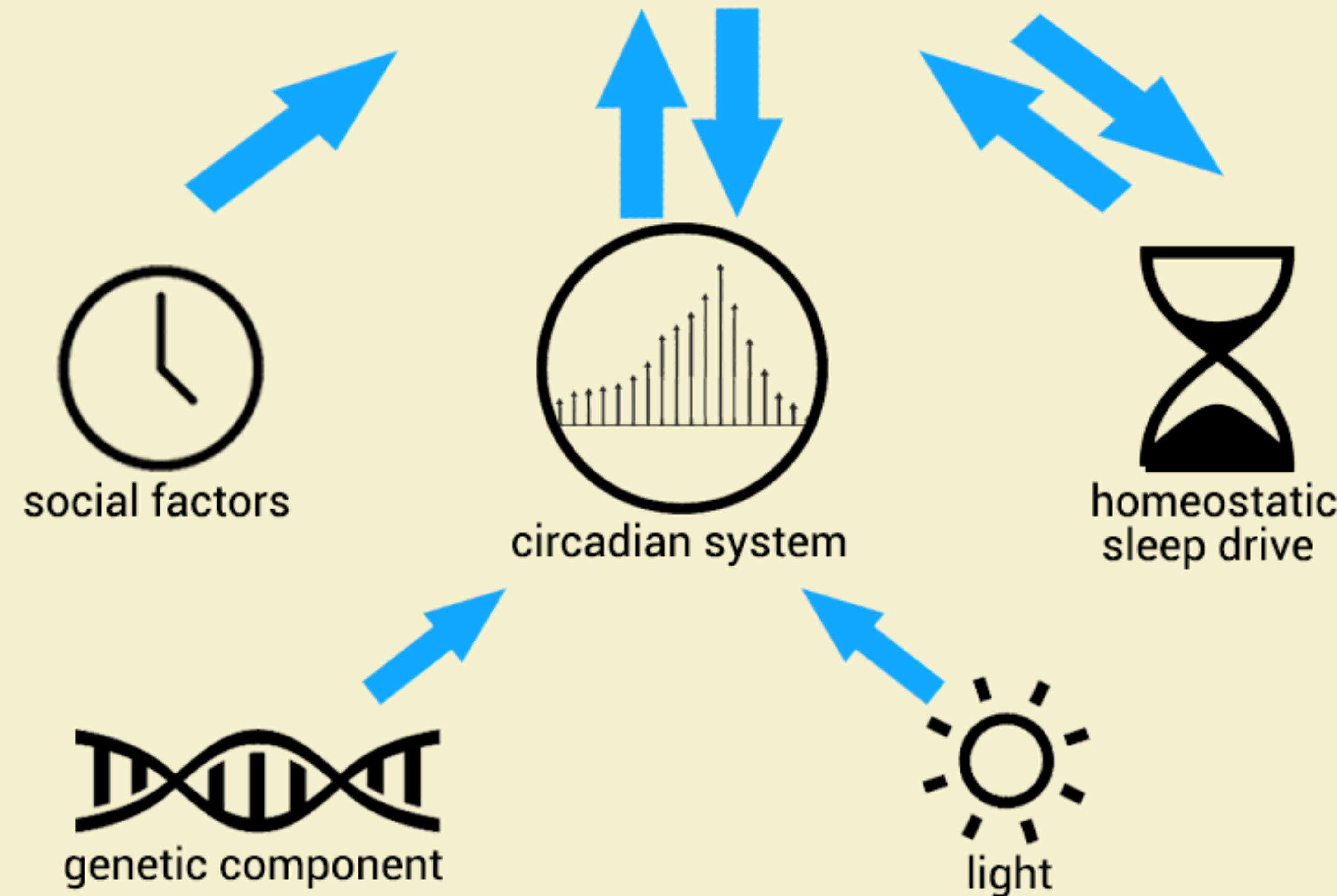


# ENTRAINMENT: EXTERNAL CUES FOR SYNCHRONIZATION WITH ENVIRONMENT



**CHRONOTYPE:**  
INDIVIDUAL DIFFERENCE IN TEMPORAL  
PREFERENCES DUE TO GENETICS AND  
ENVIRONMENTAL FACTORS

# sleep-wake cycle



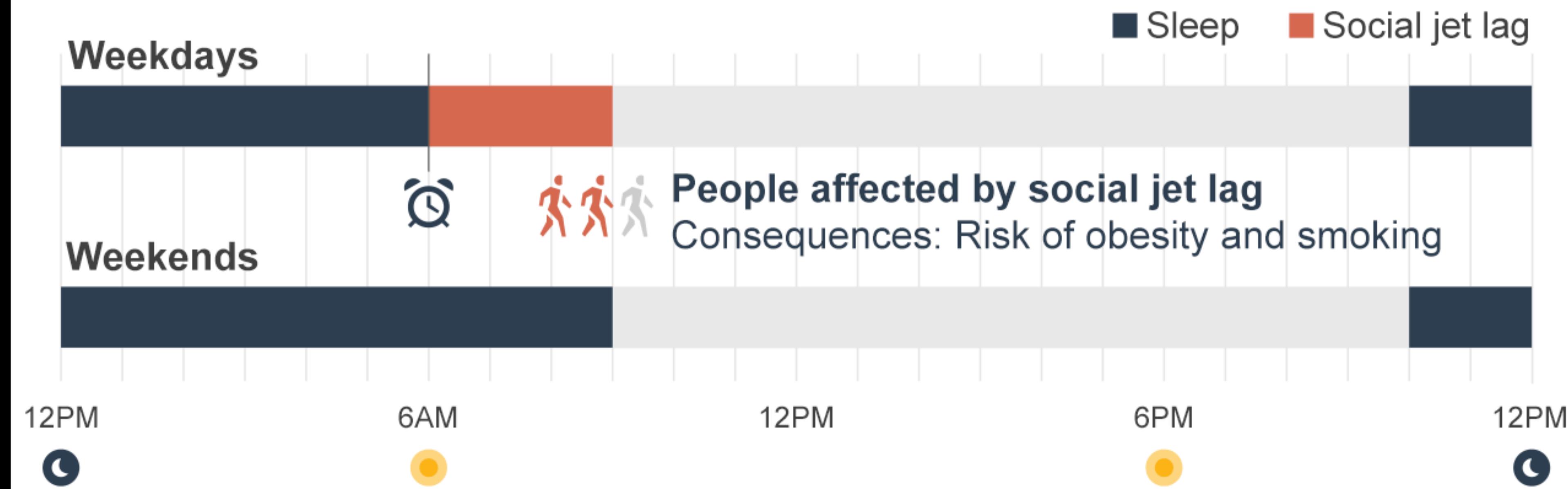
MOST OF US **CAN'T** AND  
**SHOULDN'T** MAINTAIN "EARLY TO  
BED AND EARLY TO RISE" LIFESTYLE

“Instead of sleeping as our bodies dictate, we drink another cup of coffee, turn up the radio, roll down the car window and **kid ourselves** that we can beat a few **billion years of evolution.**”

—RUSSELL FOSTER  
CIRCADIAN NEUROSCIENTIST

DISRUPTIONS IN BODY CLOCK  
RESULTS IN SYMPTOMS SIMILAR  
TO JET LAG

# 80% OF POPULATION SUFFERS FROM SOCIAL JET LAG



CONTINUED DISRUPTIONS INCREASES  
RISK FOR CANCER, DIABETES,  
CARDIOVASCULAR DISEASES AND  
MENTAL HEALTH PROBLEMS

# HOW TO MEASURE DISRUPTIONS IN LARGE SCALE?

## Munich ChronoType Questionnaire (MCTQ)

Please enter your age, gender, etc.. This information is important for our evaluations

Age: \_\_\_\_\_ female      male      Height \_\_\_\_\_ Weight \_\_\_\_\_

### On work days ...

I have to get up at... \_\_\_\_\_ o'clock  
 I need... \_\_\_\_\_ min to wake up  
 I regularly wake up... before the alarm      with the alarm  
 From... \_\_\_\_\_ o'clock I am fully awake  
 At around... \_\_\_\_\_ o'clock, I have an energy dip  
 On nights before workdays, I go to bed at \_\_\_\_\_ o'clock...  
 ... and it then takes me... \_\_\_\_\_ min to fall asleep

If I get the chance, I like to take a siesta/nap ...

correct	I then sleep for... _____ min
not correct	I would feel terrible afterwards

### On free days (please only judge normal free days, i.e., without parties etc.) ...

My dream would be to sleep until... \_\_\_\_\_ o'clock  
 I normally wake up at... \_\_\_\_\_ o'clock  
 If I wake up at around the normal (workday) alarm time, I try to get back to sleep...  
 correct      not correct  
 if I get back to sleep, I sleep for another... \_\_\_\_\_ min  
 I need... \_\_\_\_\_ min to wake up  
 From... \_\_\_\_\_ o'clock I am fully awake  
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once I am in bed, I would like to read for ... \_\_\_\_\_ min, ...  
 ... but generally fall asleep after no more than ... \_\_\_\_\_ min.

I prefer to sleep in a completely dark room      correct      not correct  
 I wake up more easily when morning light shines into my room      correct      not correct

How long per day do you spend on average outside (really outside) exposed to day light?

On work days: \_\_\_\_\_ hrs. \_\_\_\_\_ min.      On free days: \_\_\_\_\_ hrs. \_\_\_\_\_ min.

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**MID-SLEEP POINT (MS)=**  
**SLEEP ONSET + SLEEP DURATION/2**

CHRONOTYPE =  $MS_{\text{FREE-DAY}}$

DISRUPTION =  $|MS_{\text{FREE-DAY}} - MS_{\text{WORK-DAY}|}$

CLINICALLY **VALIDATED** AGAINST  
BIOCHEMICAL MEASUREMENTS

LONG TERM TRACKING  
IS DIFFICULT

DETECTING  
INSTANTANEOUS CHANGES  
NOT FEASIBLE

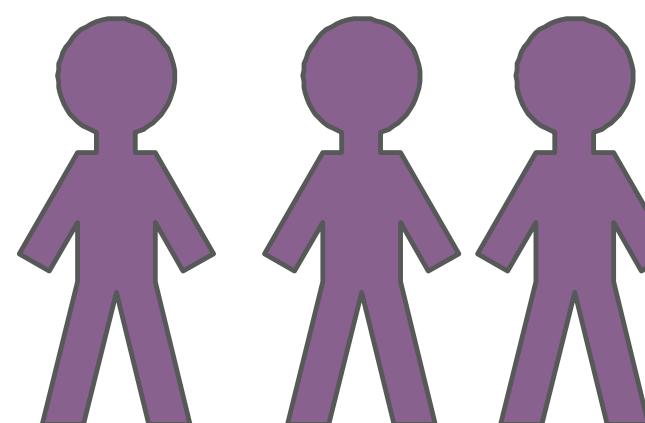
“we still do not have answers to the most basic questions [...] To transform our understanding of sleep, a broad data-collection strategy is required [using] indicators that sidestep conventional markers of circadian rhythms”

-TILL ROENNEBERG IN NATURE. JUNE, 2013

WHAT CAN YOUR PHONE USAGE  
TELL ABOUT YOU?

# IS SMARTPHONE USAGE PATTERN INDICATIVE OF CIRCADIAN MISALIGNMENTS?

# STUDY



7 males, 2 females

November						
Su	Mo	Tu	We	Th	Fr	Sa
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

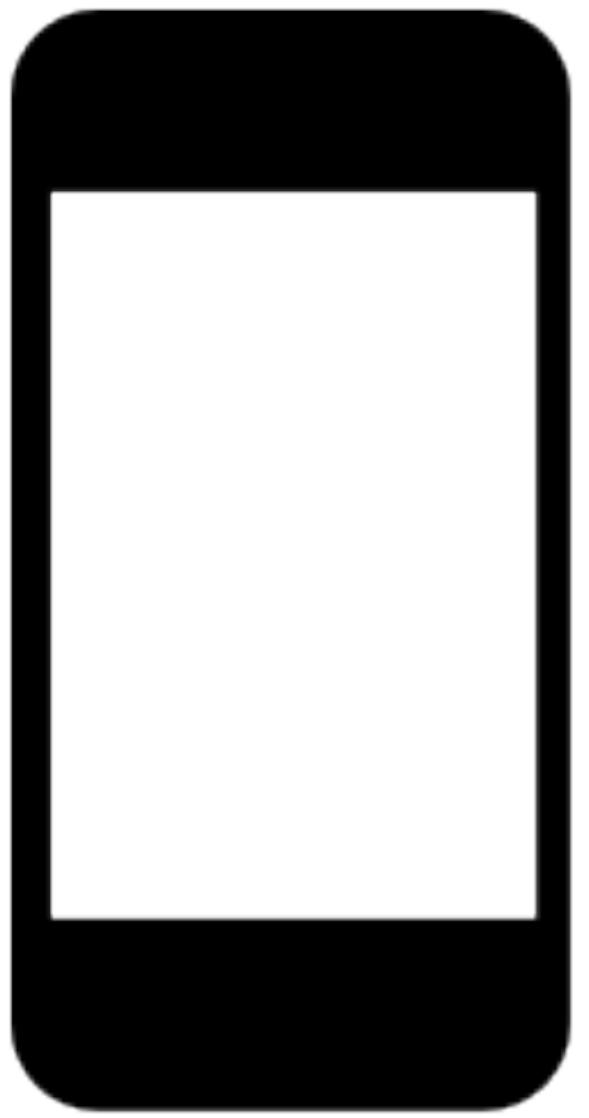
December						
Su	Mo	Tu	We	Th	Fr	Sa
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

January						
Su	Mo	Tu	We	Th	Fr	Sa
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

February						
Su	Mo	Tu	We	Th	Fr	Sa
1						
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	

97 days spanning fall, winter  
break and spring

# STUDY



Phone Usage



Sleep Journal

## Munich ChronoType Questionnaire (MCTQ)

Please enter your age, gender, etc.. This information is important for our evaluations

Age: \_\_\_\_\_ female    male    Height \_\_\_\_\_ Weight \_\_\_\_\_

**On work days ...**

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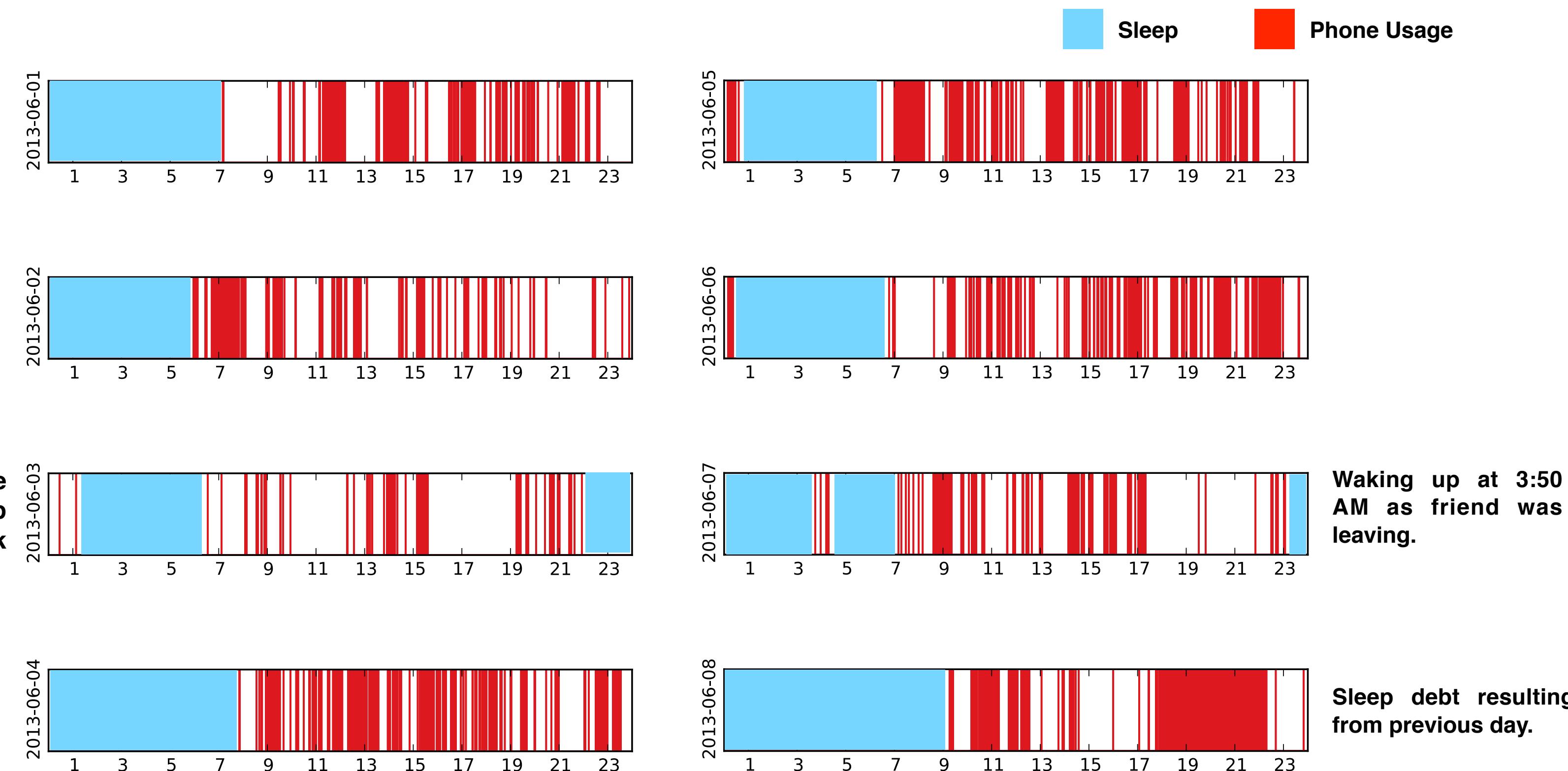
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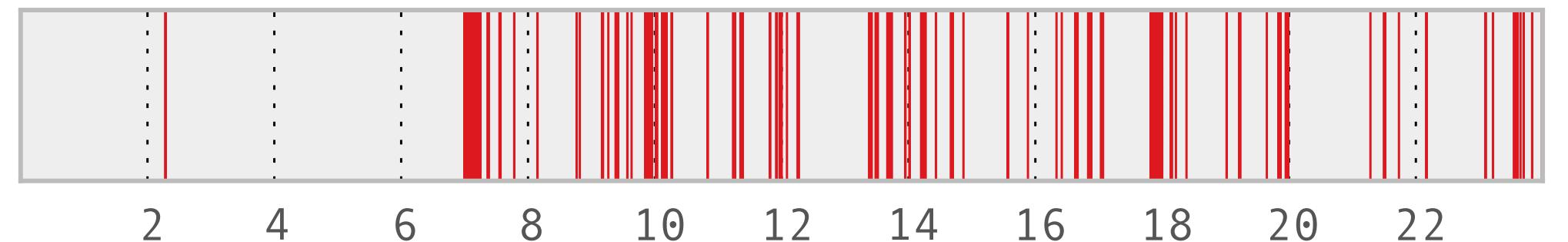
© 2002, Till Roenneberg and Martha Merrow, LMU Munchen.

ONE PARTICIPANT WITH EARLY  
BODY CLOCK TYPE

# PHONE USAGE ALIGNS WITH SLEEP PATTERN



## Screen On/Off

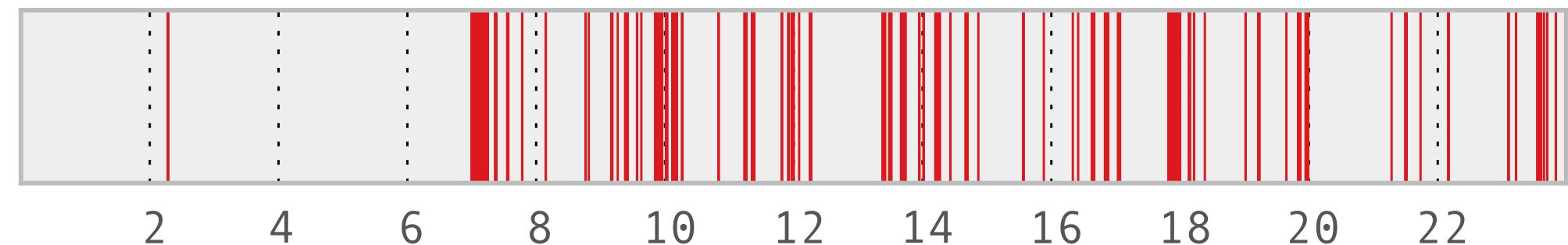


Filtering out non-active  
interaction

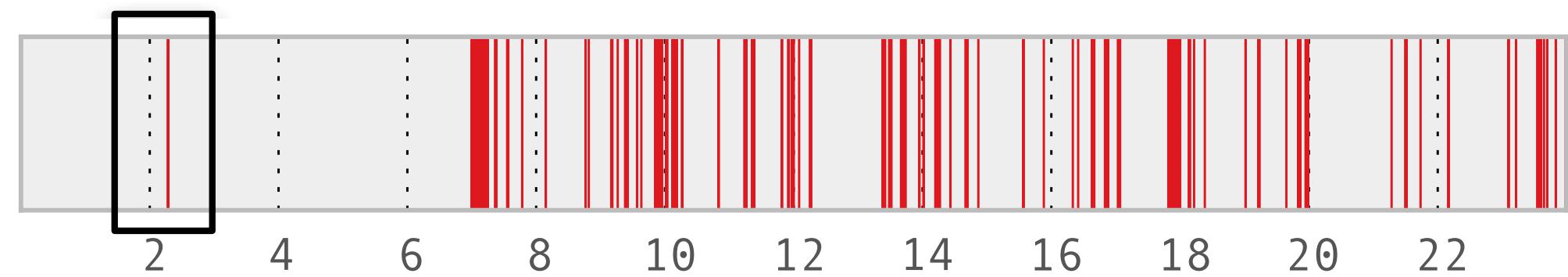
Non Usage pattern

Corrective Term for  
Personalization

# Screen On/Off



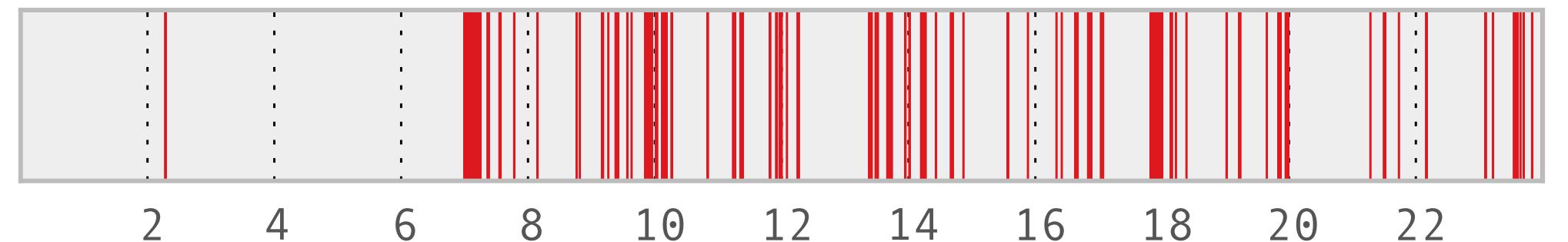
Filtering out non-active interaction



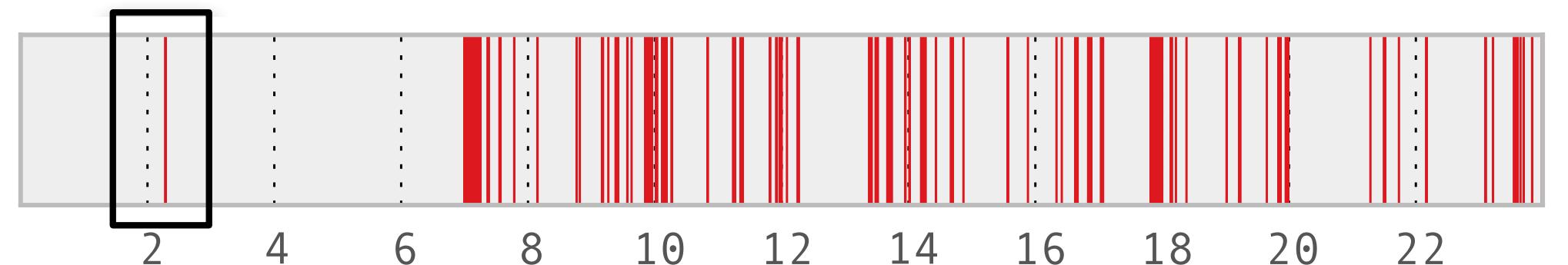
Non Usage pattern

Corrective Term for Personalization

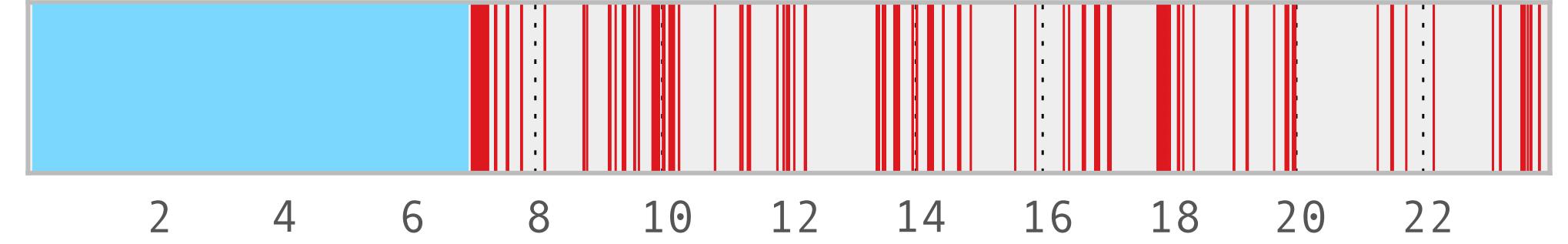
## Screen On/Off



Filtering out non-active interaction

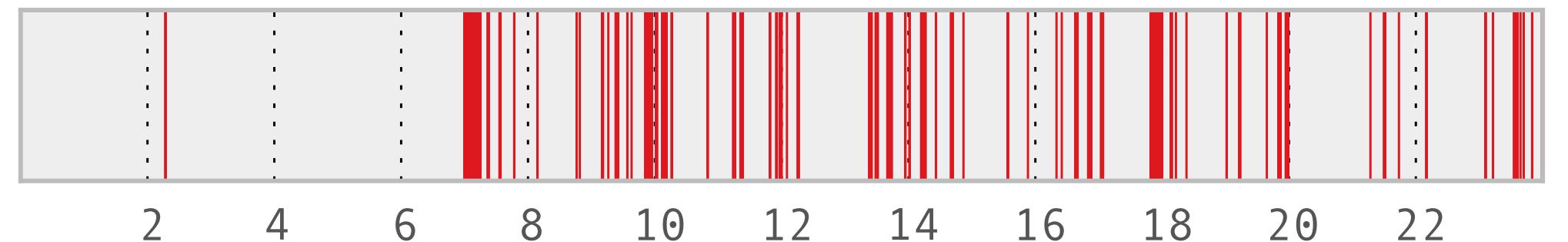


Non Usage pattern

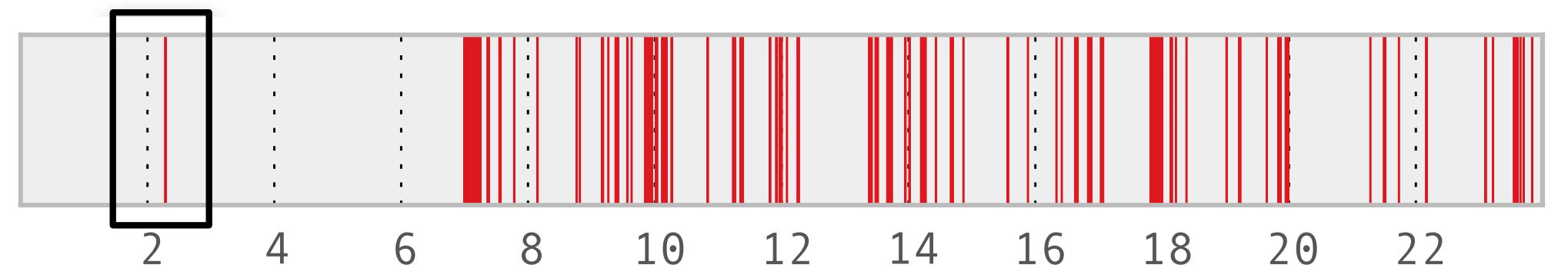


Corrective Term for Personalization

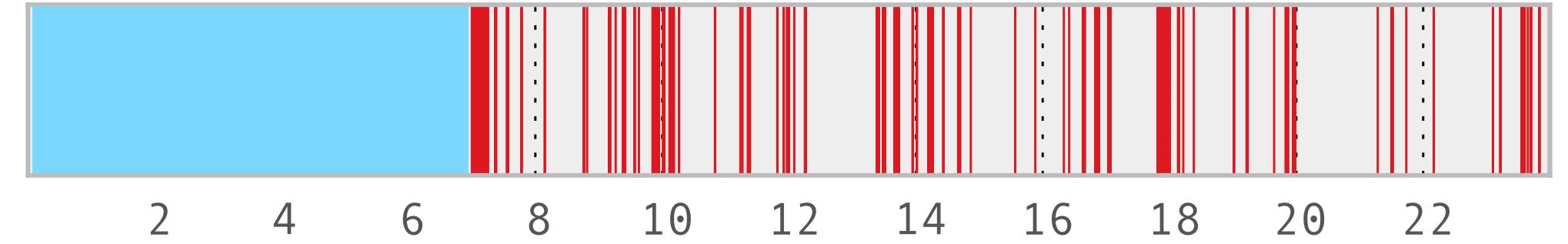
## Screen On/Off



Filtering out non-active interaction



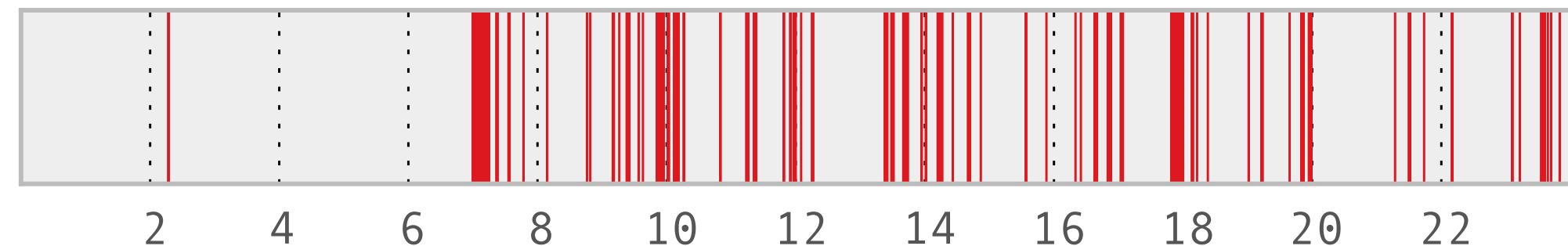
Non Usage pattern



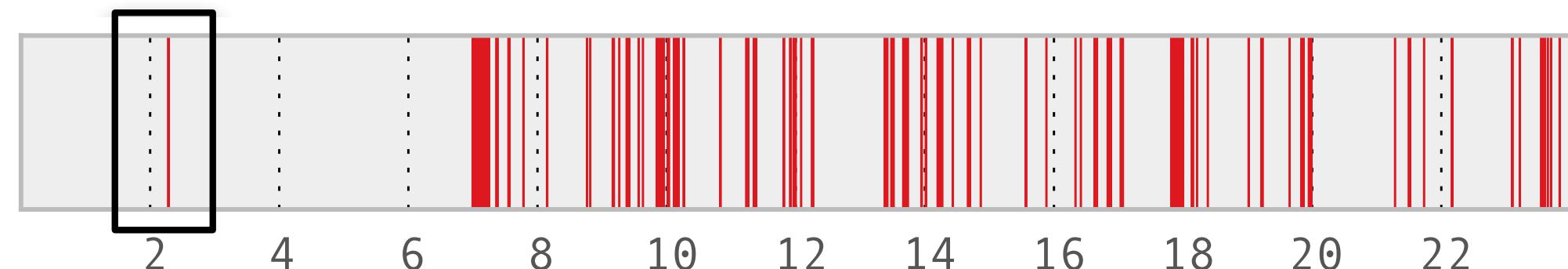
Corrective Term for Personalization

First two weeks of journal data

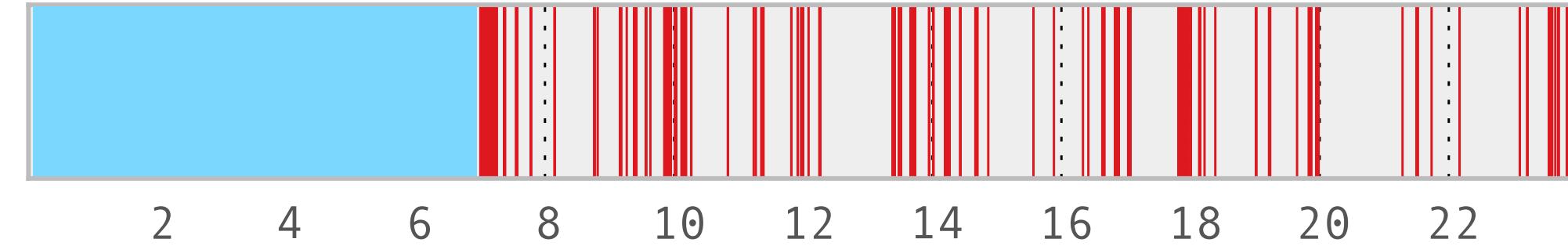
## Screen On/Off



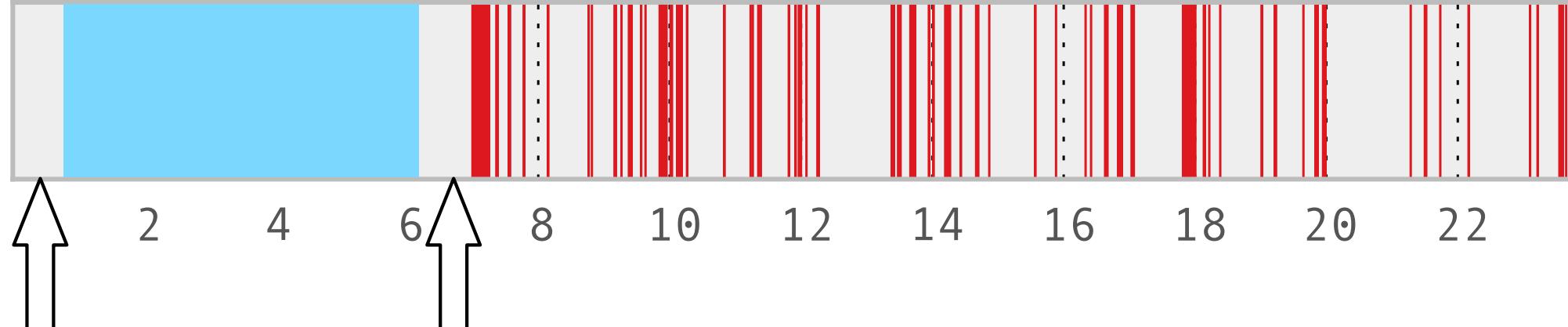
## Filtering out non-active interaction



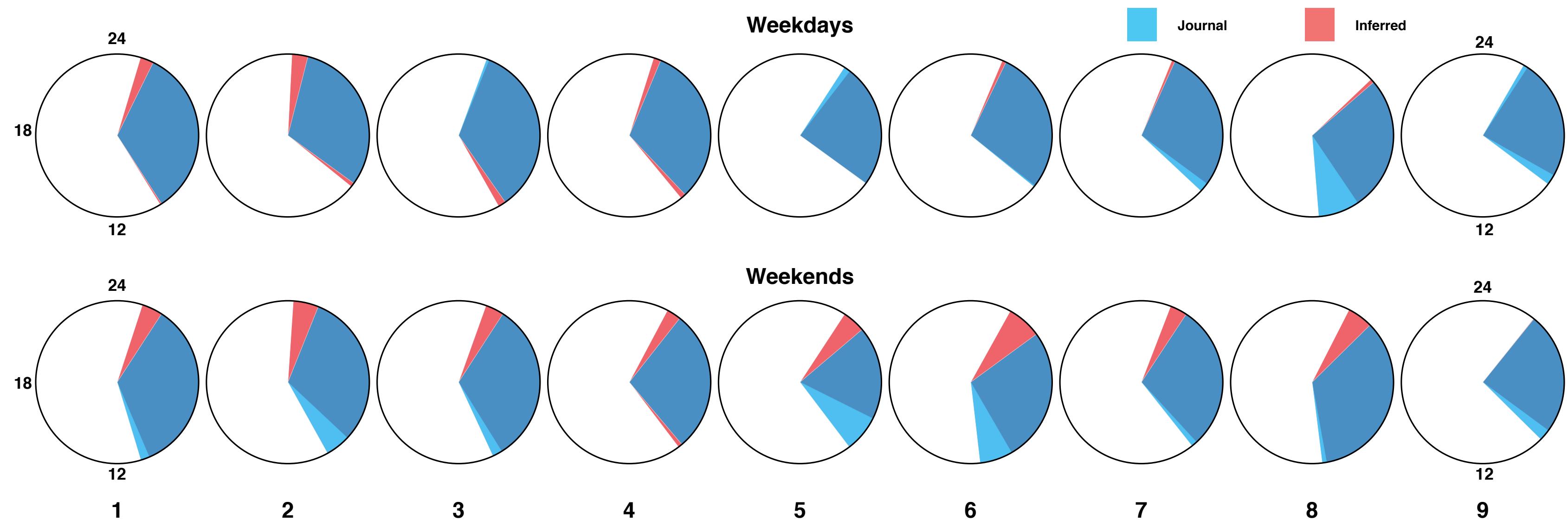
## Non Usage pattern



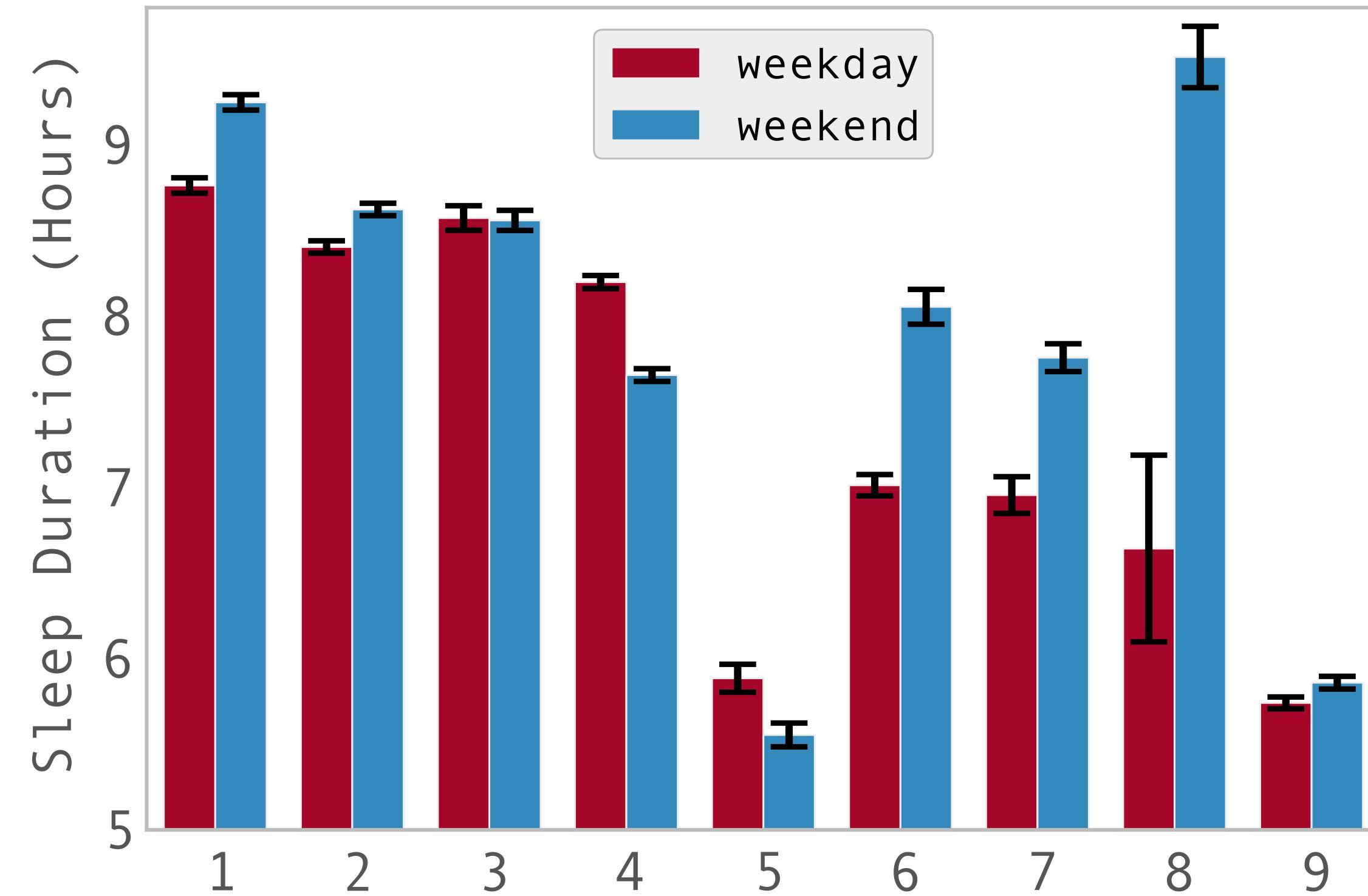
## Corrective Term for Personalization



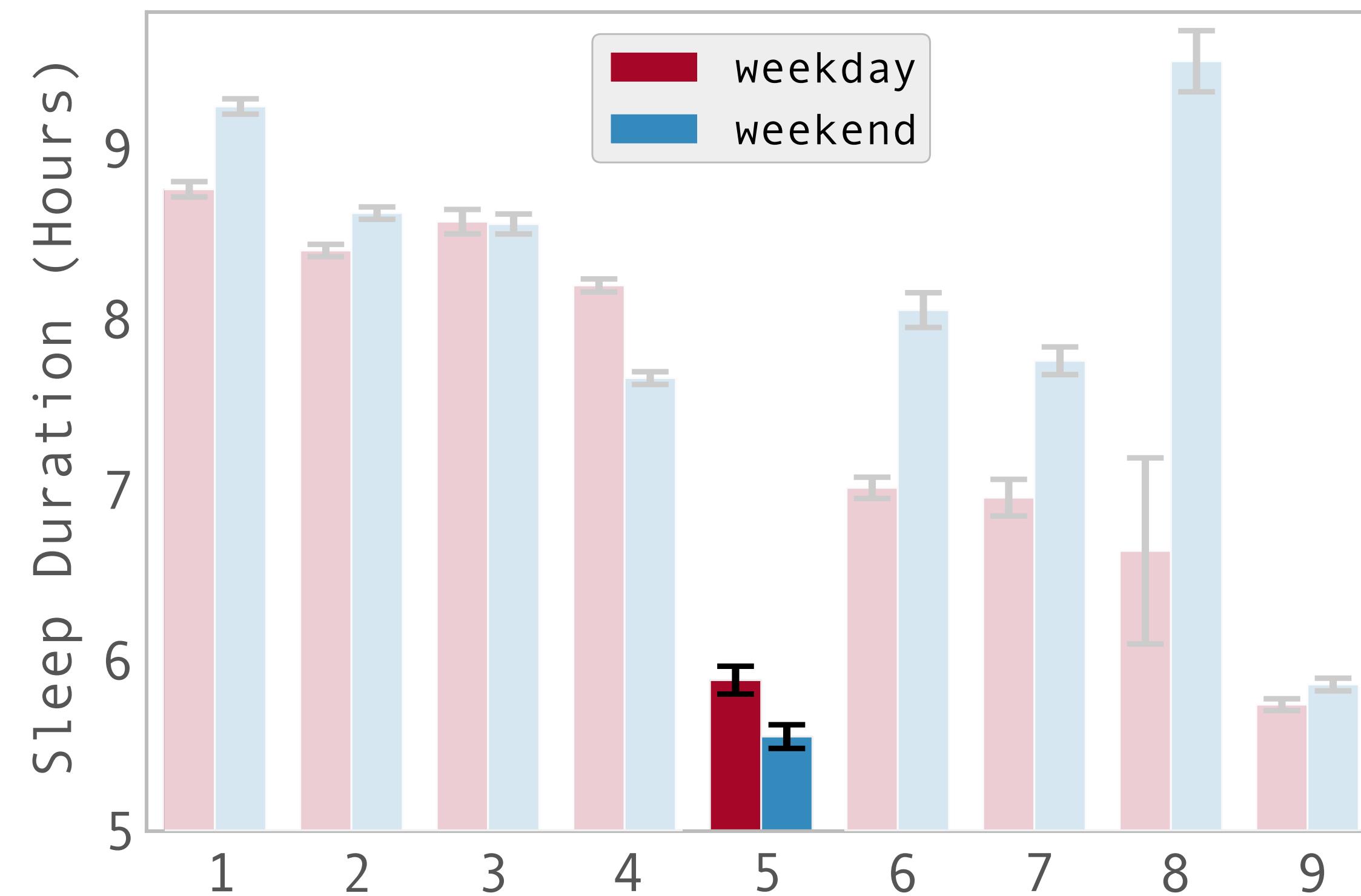
# SLEEP MIDPOINT FALLS WITHIN 23.8 MINS OF GROUND TRUTH



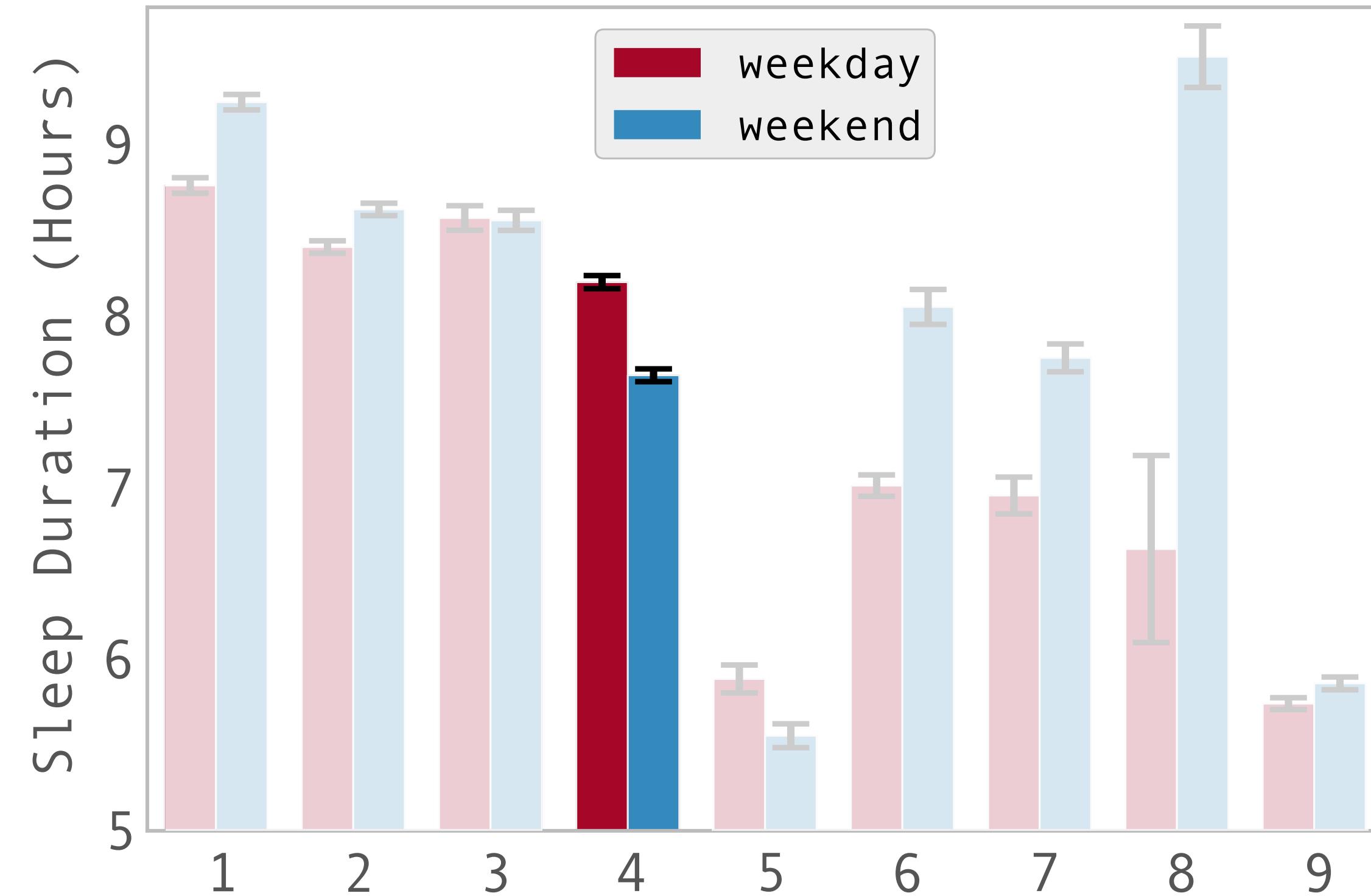
# CIRCADIAN MISALIGNMENT DETECTED FROM PHONE USAGE



# CIRCADIAN MISALIGNMENT DETECTED FROM PHONE USAGE

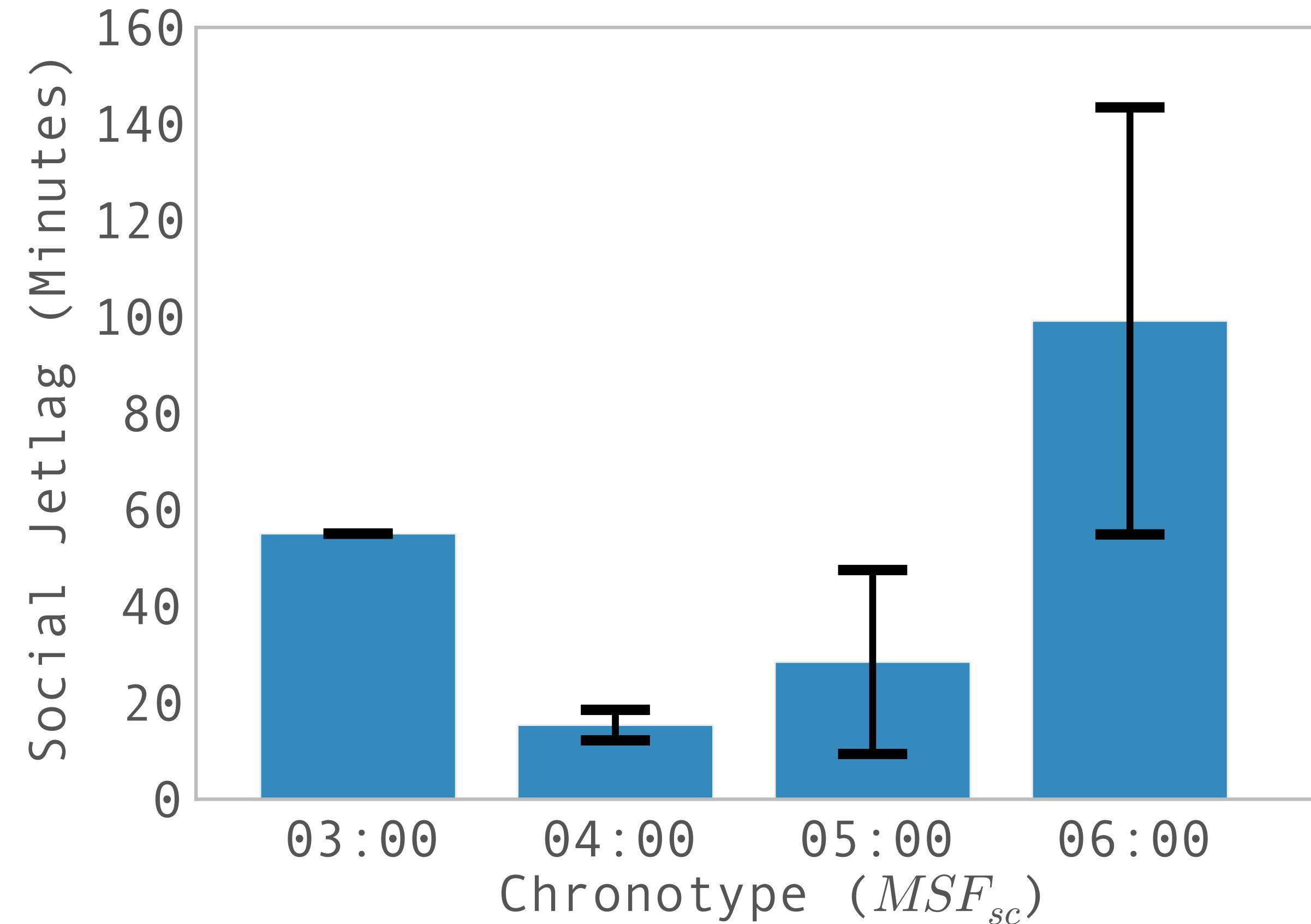


# CIRCADIAN MISALIGNMENT DETECTED FROM PHONE USAGE



# SOCIAL JET LAG INFERRED FROM PHONE USAGE

LATE TYPES SUFFER MORE FROM SLEEP DEBT



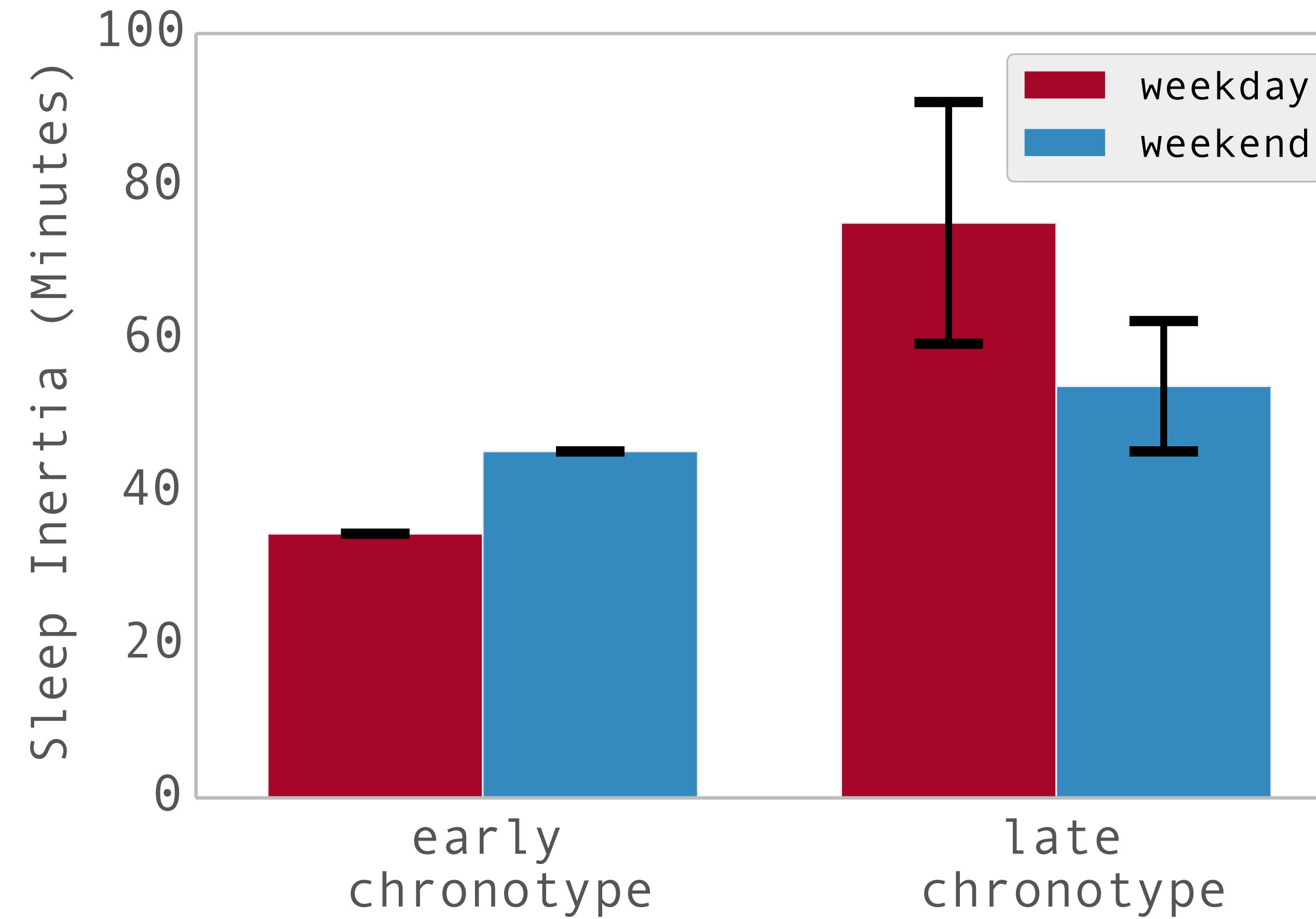
# SLEEP INERTIA TRANSITIONAL PERIOD FROM SLEEP TO FEELING WAKE

INDICATIVE OF SLEEP DEBT AND CIRCADIAN DISRUPTION

PARTICIPANTS OFTEN USE PHONE AS A WAY TO WAKE UP  
**SLEEP INERTIA**  
TOTAL MINUTES OF ACTIVE PHONE  
USAGE IN THE MORNING

# SLEEP INERTIA DIFFERS ACROSS CHRONOTYPES

LATE TYPES: **WEEKDAYS**   EARLY TYPE: **WEEKENDS**



# PHONE USAGE PATTERN INDICATES CIRCADIAN MISALIGNMENTS

- For “habituated” smartphone users, sleep events aligns with phone usage
- Usage difference across body clock types is consistent with clinical findings
- Circadian disruptions reflect on phone usage

SO, WHAT'S IN IT FOR  
UBICOMP COMMUNITY?

# CIRCADIAN COMPUTING SYSTEMS THAT PLAY TO OUR BIOLOGICAL STRENGTH

- Personalized clock that recommends best time for specific task: **reading paper** vs. **doing laundry**
- Calendar that schedules events based on **body clock type**



DEPENDING ON THE TASK, THE PERFORMANCE  
CHANGE ACROSS THE DAY CAN BE EQUIVALENT  
TO DRINKING THE LEGAL LIMIT OF ALCOHOL

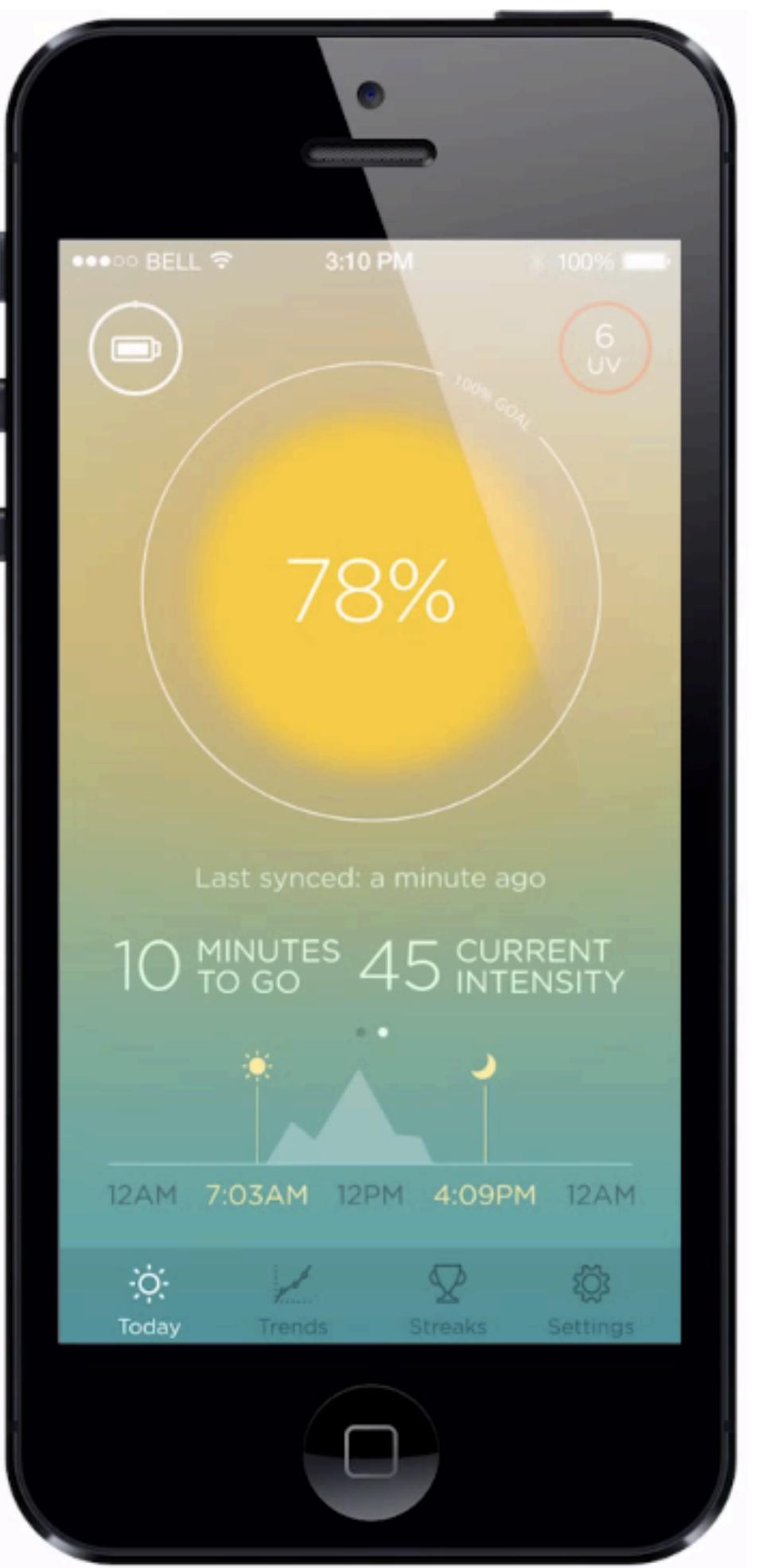
# HEALTH RHYTHMS

- **4 AM** Asthma attack
- **6 AM** Hay fever, Rheumatoid arthritis
- **7 AM** Angina pains, heart attack and strokes
- **3-6 PM** Osteoarthritis
- **11 PM** Allergic response begins to increase

SLEEP FINDINGS AND RECOMMENDATIONS  
NOT CONSIDERING CIRCADIAN  
ASPECTS WILL GET HALF THE  
PICTURE AT BEST

HOW TO FIX A BROKEN CLOCK?

YOU CAN'T CHANGE YOUR GENES,  
BUT YOU CAN CHANGE  
ENVIRONMENTAL FACTORS



# BEYOND PERSONALIZATION: WHEN IS THE **RIGHT TIME**?

“We can manage the continued development of the 24-hour society [using] pharmacological intervention or light based therapy to counteract biological downside; or we can [...] attempt to reverse the breakdown of the traditional temporal structure. The choice, as ever, is not completely free but it is one that we have to make.”

–RUSSELL FOSTER  
CIRCADIAN NEUROSCIENTIST

# THANK YOU

Media Credit: BBC, Spiegel Online, Wikimedia Commons,  
SG Saupe, SunSprite.