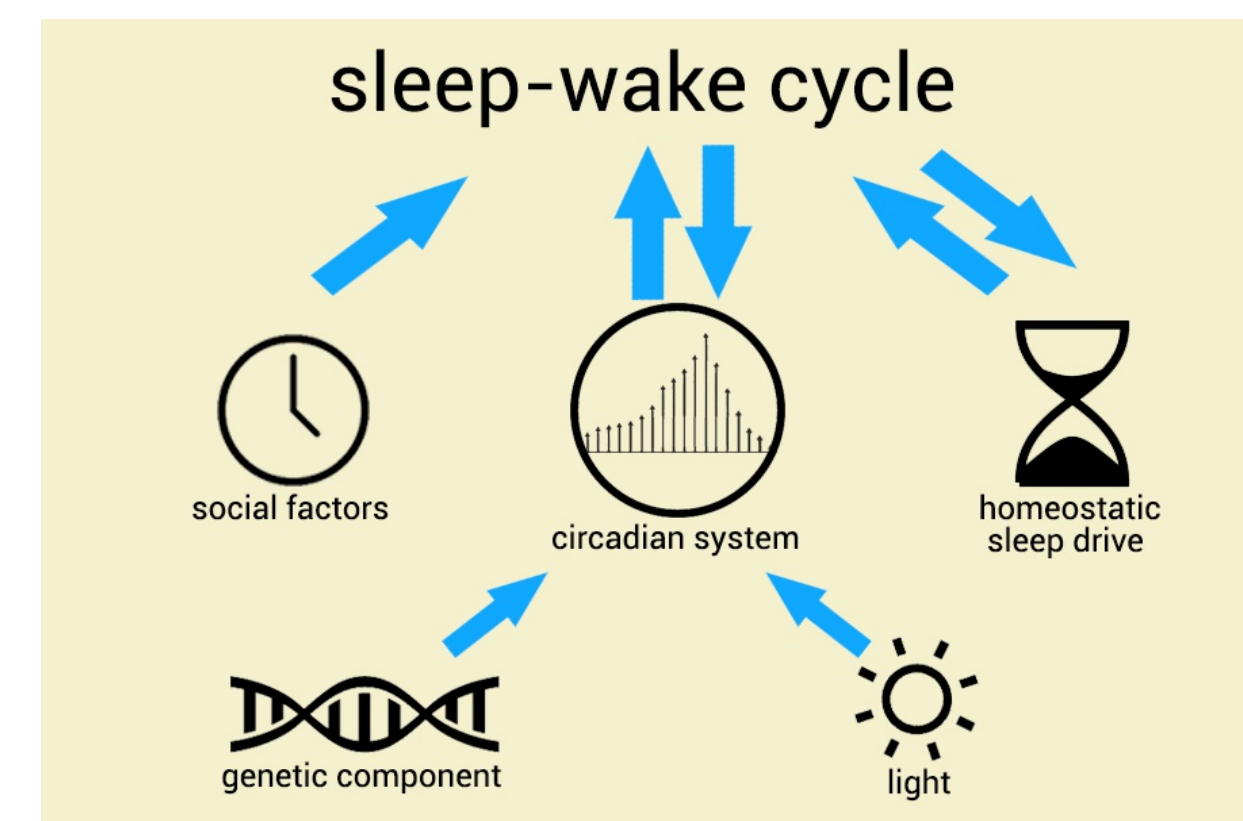


# Towards *Circadian Computing*: "Early to Bed and Early to Rise" Makes Some of Us Unhealthy and Sleep Deprived

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## Introduction



Biological Rhythms guide our life. Continued disruption of biological rhythms often has serious consequences for physical and mental well-being.

We investigate whether such disruptions can be detected from smartphone usage data from 9 participants over 97 days. Our findings include:

- Smartphone usage aligns with sleep onset and duration
- Detecting biomarkers of body clock misalignments from usage patterns
- Identifying opportunities for body clock aware systems and broad range of interventions

## Circadian Rhythm & Social Jet lag

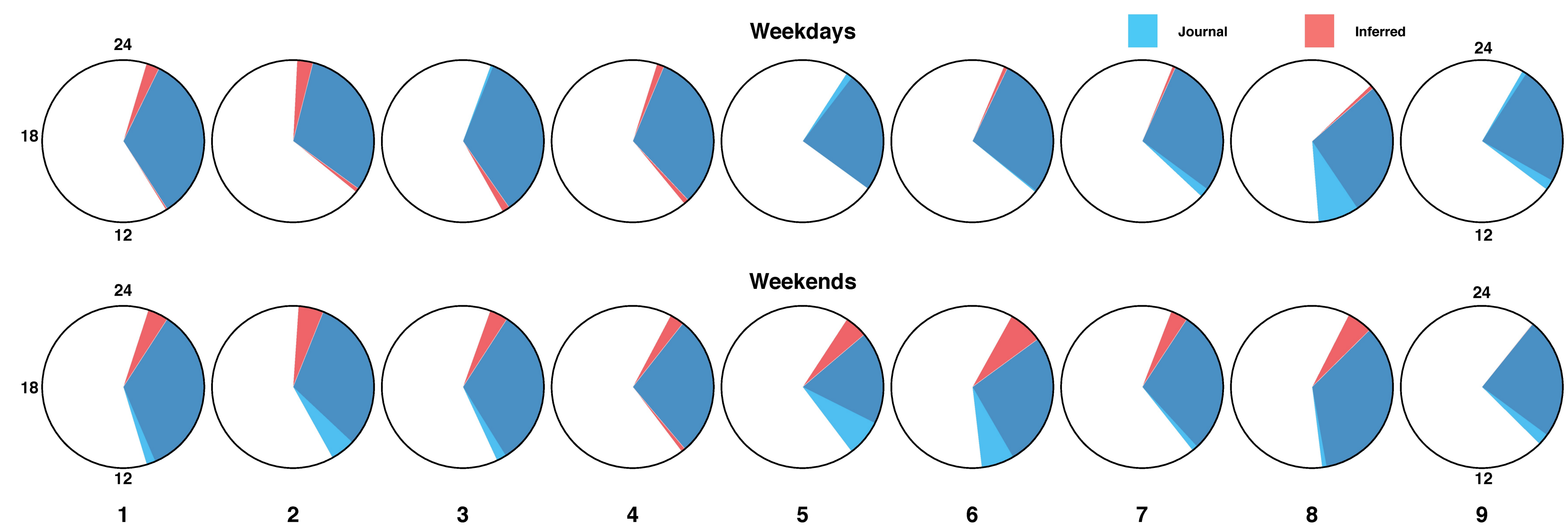


For some people social jet lag could be the equivalent of a return weekend transatlantic flight

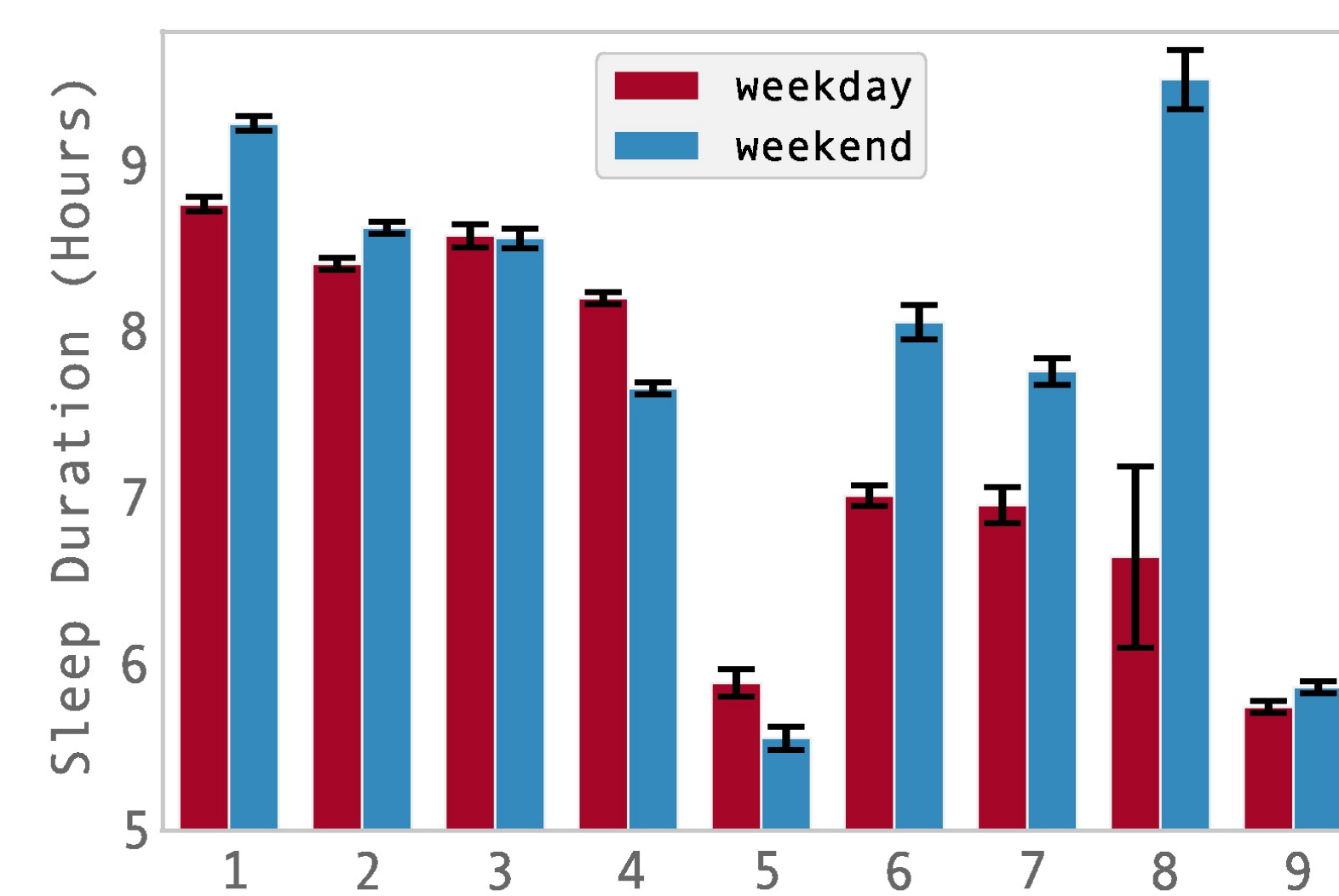


- Circadian (circa: about, diem: a day) rhythms result from roughly 24 hour periodicity of biological processes
- Chronotype: Individual difference in temporal preferences (early vs late risers) that depends on genetic and environmental factors
- Misalignments between societal and internal clocks can disrupt circadian system similar to jet lag

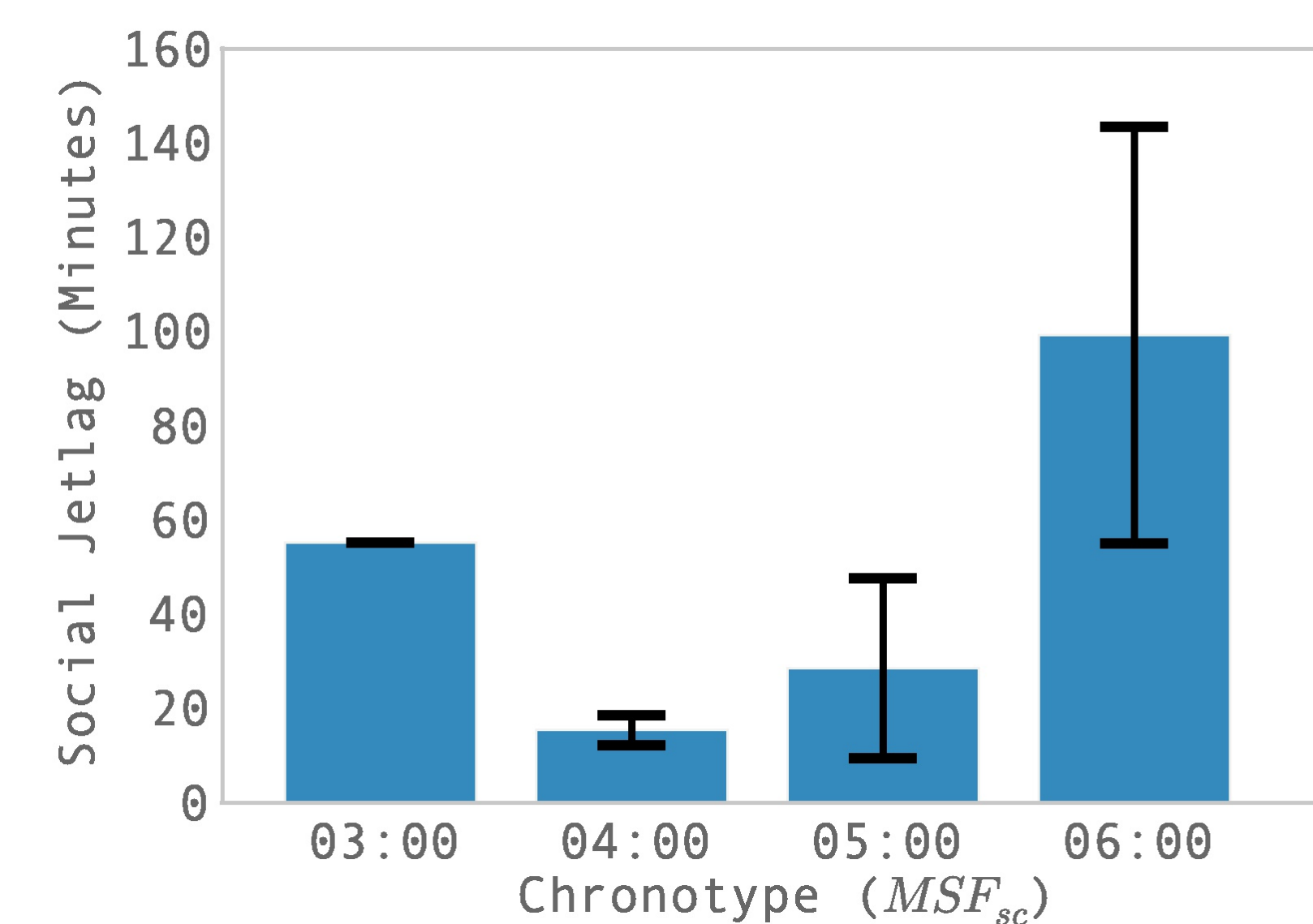
## Sleep Onset and Duration Aligns with Phone Usage



## Smartphone Usage for Inferring Social Jet lag



Sleep difference between weekday and weekend indicates circadian misalignment

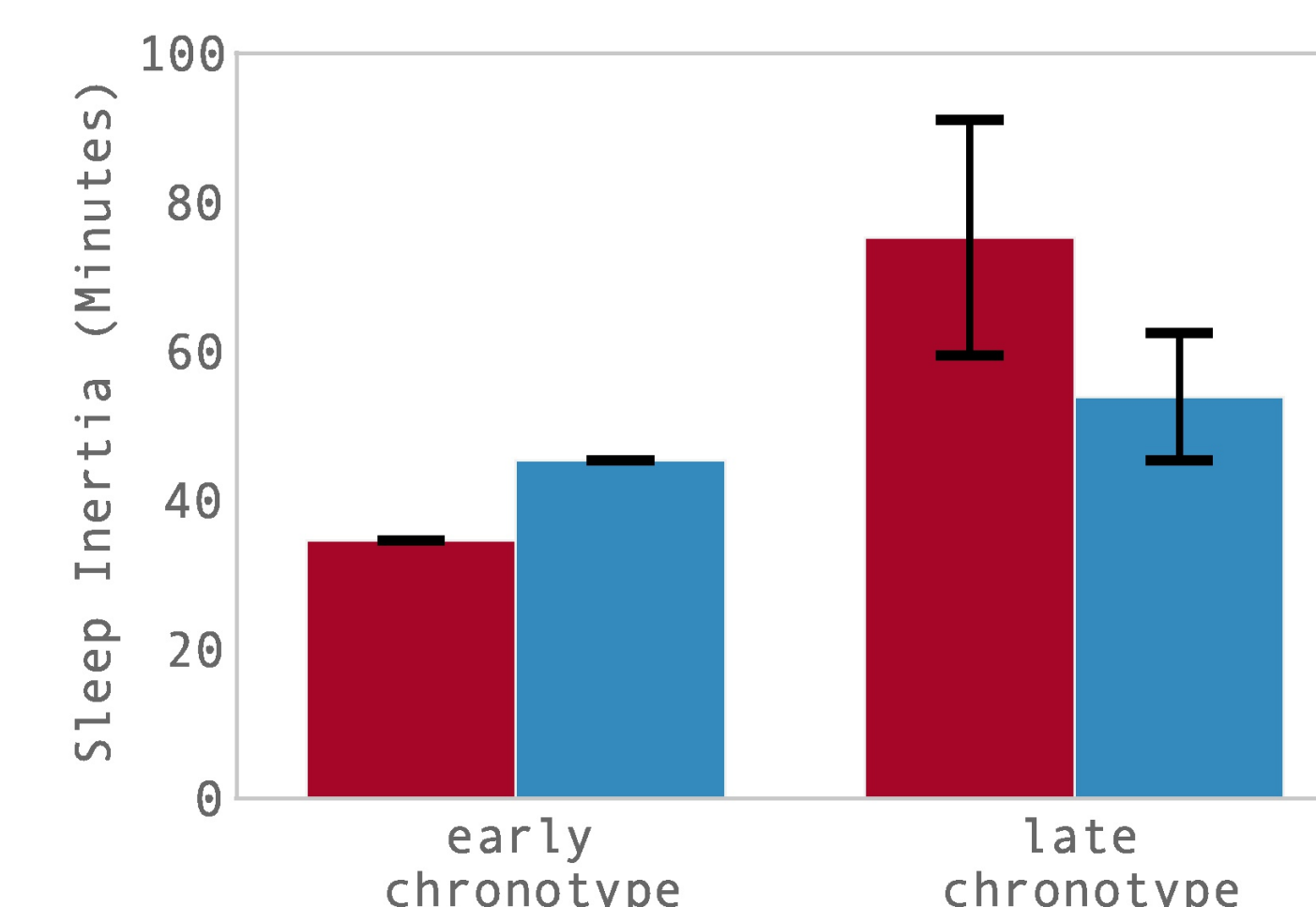


Later body clock types suffer more from sleep debt and social jet lag

## Sleep Inertia and Phone Usage Duration

- Sleep Inertia: A transitional period from sleep to feeling fully awake
- It is characterized by disorientation of behavior as well as impaired cognitive and behavioral performance
- Sleep debt can result in longer sleep inertia
- Prolonged sleep inertia has been shown to negatively affect attention, performance, and mood

We define sleep inertia as the total minutes of active phone usage in the morning.



Difference in sleep inertia reflects the patterns of accumulated sleep debt of different chronotypes

## Fixing A Broken Clock



Misalignment in internal clock over long period of time can result in serious health issues. For example, there is an increased risk of cancer for night shift workers. Circadian rhythms are also central to many mental illnesses including bipolar disorder, schizophrenia and depression.

We are working on building individual rhythm coach that would provide actionable suggestions and feedback to help stabilize the internal clock — suggesting light exposure in opportune time, for example.

## Circadian Computing



Reliable detection of idiosyncratic circadian variations also opens up possibility of developing circadian friendly systems:

- Calendar application that schedules events based on body clock type
- Personalized clock that recommends best time for specific task, e.g., reading paper vs. doing laundry
- System suggesting time to take medication for maximum efficacy

