# the perfect storm:

sleep, circadian rhythms, & the environmental context of the developing child

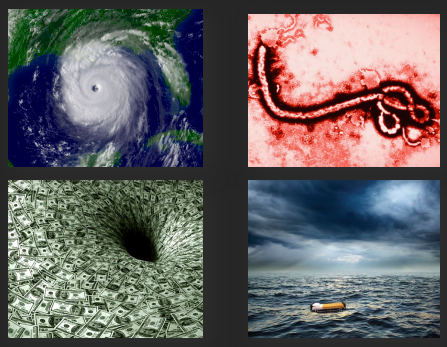
**Monique K. LeBourgeois, PhD**
Department of Integrative Physiology
University of Colorado Boulder

Funding: K01-MH074643, R01-MH086566, University of Colorado Boulder

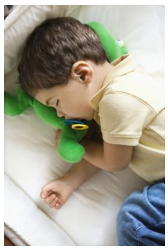
## today's talk

- emily's story
- theoretical frameworks for studying sleep in early childhood
- fundamental data on the sleep and circadian systems in early childhood
- consequences of a mismatch or "poor fit" between children's physiology & their environment
- interpret findings within social contexts

*"… a unique set of events converge to result in a negative outcome."*



## why care about sleep in kids?

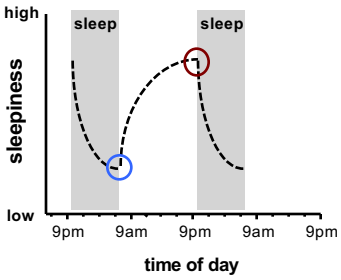


- sleep: primary behavioral state
- changes in sleep timing & duration
- behavioral sleep problems are prevalent
  - resist bedtime / call out / curtain calls
  - difficulties falling asleep
  - difficulties waking in morning
- early sleep difficulties persist & predict long-term mood & cognitive difficulties
- short sleep in childhood increases risk of overweight & obesity
- sleep is a changeable health behavior

## goodness of "fit" perspective

Jenni & LeBourgeois, *Current Opinions in Psychiatry*, 2006

## homeostatic sleep process

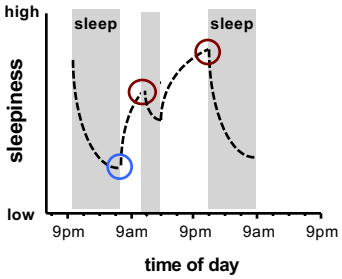



**sleep "pressure":**

- sleep pressure increases with longer time awake and dissipates with sleep
- sleepiness lowest in the morning – highest in the evening

Borbély, *Human Neurobiology*, 1982

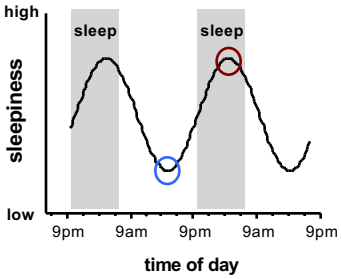
## homeostatic process: little kids




**early childhood:**

- napping is common
- naps provide midday dissipation of sleep pressure
- may delay nighttime sleep
- optimal time of naps?
- optimal duration of naps?

## circadian process

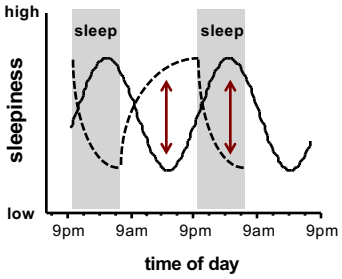



**circadian timing system:**

- 24-hour clock-like system
- sleep pressure oscillates with a daily variation
- lowest at the end of the day - highest during the middle of the night

Borbély, *Human Neurobiology,* 1982

## sleep & circadian processes interac




**interaction of 2 systems:**

- day: increase in homeostatic sleep pressure opposed by the increase in circadian alertness = wakefulness
- night: high circadian sleep pressure counteracts declining homeostatic sleep pressure = sleep continuity
- keeps us awake during the day & asleep at night

## sleep & circadian science informs policy

delaying school start times for high-school students

instituting federal policies for long-haul truck drivers

restricting the number of hours worked by medical residents

## participants & longitudinal timeline

- good sleepers in excellent health (at age 2-years)
- consistent sleep-wake schedule & daily nap opportunity
- no travel across >2 times zones (8 weeks before study)
- no family history of psychiatric illness, narcolepsy, OSA
- multiple training visits

**30 day in-home protocol (~100 hours per child)**

- daily actigraphy, sleep diary, phone/email contact
- EEG recordings, dim light melatonin (DLMO), behavioral assessments

**annual assessments**

preschool → kindergarten

2 Years — 3 Years / 4 years — 5 Years

Journal of Biological Rhythms

Circadian Phase and Its Relationship to Nighttime Sleep in Toddlers

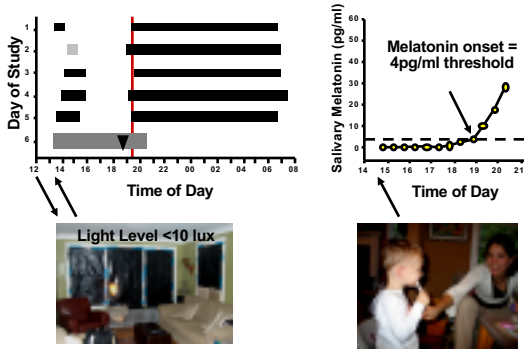
Monique K. LeBourgeois,*,† Mary A. Carskadon,‡ Lameese D. Akacem,* Charles T. Simpkin,* Kenneth P. Wright, Jr.,‖ Peter Achermann,§ and Oskar G. Jenni||

*Sleep and Development Laboratory, Department of Integrative Physiology, University of Colorado Boulder, Boulder, CO, USA, †Sleep and Chronobiology Laboratory, Department of Psychiatry and Human Behavior, The Warren Alpert Medical School of Brown University, Providence, RI, USA, ‡Sleep and Chronobiology Laboratory, Department of Integrative Physiology, University of Colorado Boulder, Boulder, CO, USA, §Institute of Pharmacology and Toxicology, Section of Chronobiology and Sleep Research, University of Zurich, Zurich, Switzerland, and ||Child Development Center, University Children's Hospital Zurich, Zurich, Switzerland

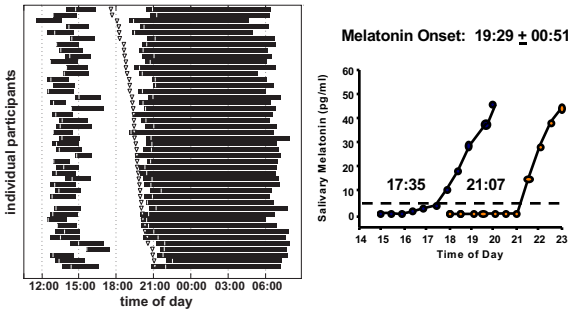
NATIONAL INSTITUTES OF HEALTH

HHMI HOWARD HUGHES MEDICAL INSTITUTE

## melatonin onset assessment

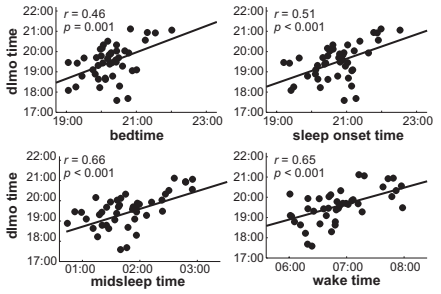



## circadian physiology in toddlers (n=45)



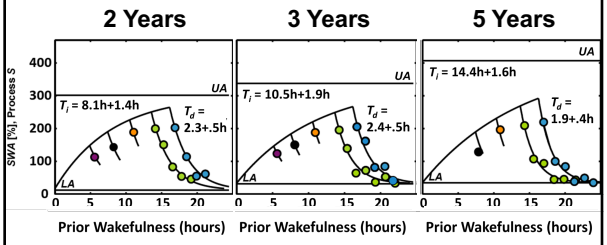

LeBourgeois, Carskadon, Akacem, Simpkin, Wright, Achermann, & Jenni, *Journal of Biological Rhythms*, 2013

## circadian phase is associated with sleep timing in toddlers




LeBourgeois, Carskadon, Akacem, Simpkin, Wright, Achermann, & Jenni, *Journal of Biological Rhythms*, 2013

## accumulation of sleep pressure slows with increasing age




## nighttime settling problems: poor fit between physiology & bedtime?

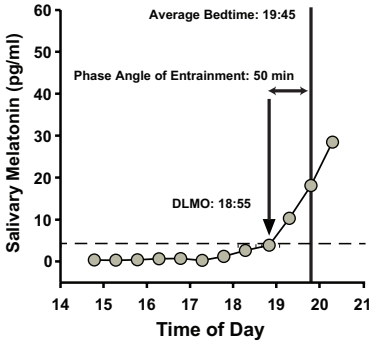
**Delayed sleep onset:**

- 26% of infants
- 51% of 3-year-olds
- 66% of 5-year-olds

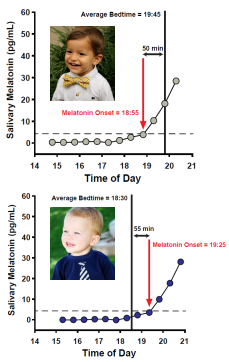
**Bedtime Resistance:**

- 7% of infants
- 42% of 3-year-olds
- 50% of 5-year-olds

## phase angle of entrainment

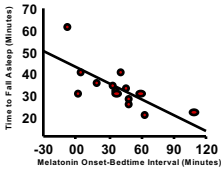


## circadian-environment interactions

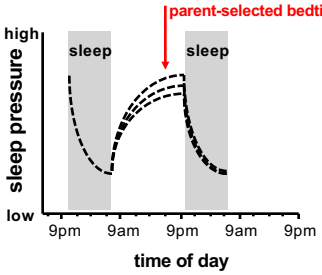


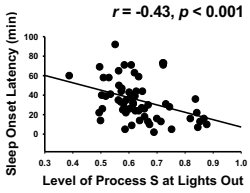

**Who will have more trouble falling asleep?**

Bobby Timmy




## sleep pressure at bedtime is associated with sleep onset latency




## sleep loss is increasingly linked to emotion processing

- in adults, sleep deprivation leads to decrements in mood and cognitive functioning
- brain imaging after sleep deprivation: disconnect between regions central to emotion processing

- important in early childhood: ~15% have emotional problems that commonly track across the lifespan
- does sleep play a role in the development of such problems?

## emotional consequences of poor fit

Toddlers meet part of their sleep need by napping

What is the effect of acute sleep restriction (nap deprivation) on children's emotion expressions?

Journal of Sleep Research

Acute sleep restriction effects on emotion responses in 30- to 36-month-old children

REBECCA H. BERGER[1], ALISON L. MILLER[2], RONALD SEIFER[3], STEPHANIE R. CARES[4] and MONIQUE K. LEBOURGEOIS[3,5]

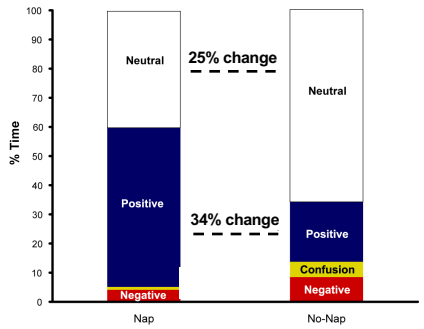
[1]Bradley/Hasbro Children's Research Center, Bradley Hospital, East Providence, RI, USA, [2]Department of Health Behavior and Health Education, The University of Michigan School of Public Health, Ann Arbor, MI, USA, [3]Department of Psychiatry and Human Behavior, The Warren Alpert Medical School of Brown University and Bradley/Hasbro Children's Research Center, East Providence, RI, USA, [4]Department of Education, Boston College, Chestnut Hill, MA, USA and [5]Department of Integrative Physiology, University of Colorado at Boulder, Boulder, CO, USA

Joy/Happiness
Pride
Interest/Excitement
POSITIVE

CONFUSION

Anxious/Worry
Sadness
Anger
Shame
Disgust
NEGATIVE

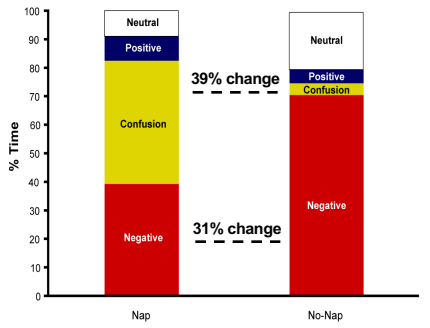
## solvable puzzle




n=10; paired t-tests; $p < 0.05$

Berger et al. (2012), *Journal of Sleep Research*

## unsolvable puzzle



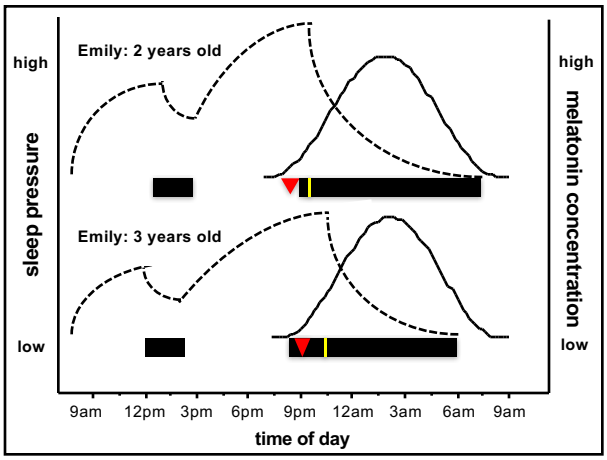

n=10; paired t-tests; $p < 0.05$

Berger et al. (2012), *Journal of Sleep Research*

## putting the pieces together

What do these findings mean for Emily and young children like her?

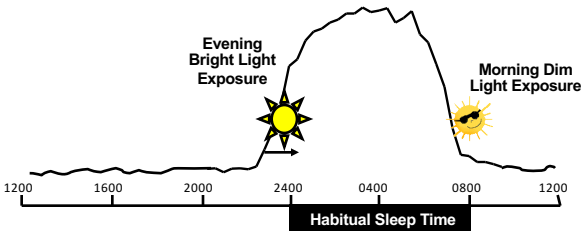
- resisting bedtime
- taking 2 hours to fall asleep
- difficult to awaken in the morning
- daytime behavioral difficulties



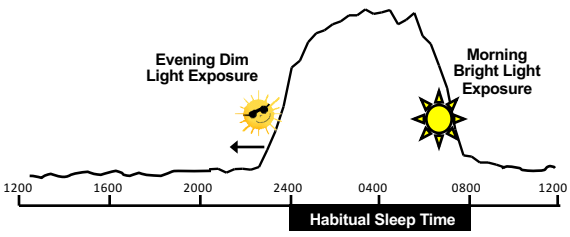

## why study light in preschoolers?

- melatonin suppressing effects of evening light in school-age children are ~2x that of adults
- children proposed to be more sensitive to light than adults – differences in eye anatomy (larger pupil size, increased light transmission rate of the lens)
- enhanced transmission rate is greatest for "blue" light (LED devices)
- media use has tripled in preschoolers in the past years – much during the hours before bedtime

## Timing of Bright Light Exposure and Dim Light/Darkness Induces a Circadian Phase Delay Shift




## Timing of Bright Light Exposure and Dim Light/Darkness Induces a Circadian Phase Advance Shift



## summary

- sleep problems are prevalent & many young children are not getting enough sleep
- understanding the development of insufficient sleep requires knowledge of interactions between physiology and the environment
- sleep loss changes behaviors associated with long-term behavioral & emotional problems
- like nutrition and exercise, sleep is a basic biological need that is essential to children's health & development

## recommendations

- make sleep a priority for parents, teachers, health care workers
- decrease the amount of stimulating activities – especially those resulting in light from electronic media – in the 1-2 hours before bedtime
- create a broader awareness of the benefits of an adequate, stable sleep


**Thanks to all the children and their families!**

**Colleagues**

Mary A. Carskadon, Brown University
Ronald Seifer, Brown University
Alison Miller, University of Michigan
Peter Achermann, University of Zurich
Oskar Jenni, University of Zurich
Kenneth Wright, CU Boulder

**Brown University**

**Research Assistants**
Rebecca Berger
Stephanie Cares
Stephan Fabregas
Katherine Garlo

**Undergraduate Students**
Becky Crossin
Herma Gebru
Colleen Gribbin
Victoria Hartman
Anjali Rao

**CU Boulder**

**Research Assistants**
Hannah Craven
Jon Lassonde
Lauren Pierpoint
Allyson Schumacher

**Graduate Students**
Lameese Akacem
Jessica Calihan
Sherin Cherian
Margaret Doucette
Charlie Simpkin
Rebekah Tribble

**Postdoctoral Fellows**
Salome Kurth
Thomas Rusterholz

**Undergraduate Students**
Cristin Bazzanella
Karlie Johansen
Alex Jones
Hannah LeBourgeois
Elsa Mullins
Ian McClain
Shane Nau

NIMH National Institute of Mental Health
FNSNF
sleep RESOURCE FOUNDATION
University of Colorado Boulder

SLEEP & DEVELOPMENT LAB
UNIVERSITY OF COLORADO BOULDER

www.colorado.edu/sleep