Why Don’t We Sleep Enough?

Mallory Avery \(^1\)  Osea Giuntella \(^1\)  \(^2\)  Peiran Jiao \(^3\)

\(^1\)University of Pittsburgh \(^2\)IZA  
\(^3\)Maastricht University & Nuffield College

6th Workshop in BEHE, Oslo  
December 14, 2018

*Preliminary and Incomplete!*
US Sleep Durations over Time: Gallup Survey, 1942-2013
Americans with insufficient sleep or obesity

Source: CDC
Why should Economists Care about Sleep?

- An economic decision, largely understudied
  (A notable exception: Biddle and Hamermesh, 1990 *JPE*)
  - Time allocation
  - A commodity that we all need (data suggest most of us need more)
  - Health capital

Growing evidence of detrimental effects on health
Substantial costs for the health care systems
Effects on human capital (cognitive skills) and productivity
Insufficient sleep also linked to motor vehicle crashes, industrial disasters (e.g., Chernobil), medical and other occupational errors
RAND estimates large economic losses due to sleep deprivation
US: 2.28% of GDP
Japan: 2.92% of GDP
Why should Economists Care about Sleep?

- An economic decision, largely understudied
  (A notable exception: Biddle and Hamermesh, 1990 *JPE*)
  - Time allocation
  - A commodity that we all need (data suggest most of us need more)
  - Health capital

- A decision with important economic consequences:
  - Growing evidence of detrimental effects on health
  - Substantial costs for the health care systems
  - Effects on human capital (cognitive skills) and productivity
  - Insufficient sleep also linked to motor vehicle crashes, industrial disasters (e.g., Chernobil), medical and other occupational errors
Why should Economists Care about Sleep?

- An **economic decision**, largely understudied
  (A notable exception: Biddle and Hamermesh, 1990 *JPE*)
  - Time allocation
  - A commodity that we all need (data suggest most of us need more)
  - Health capital

- A decision with important **economic consequences**:
  - Growing evidence of detrimental effects on health
  - Substantial costs for the health care systems
  - Effects on human capital (cognitive skills) and productivity
  - Insufficient sleep also linked to motor vehicle crashes, industrial disasters (e.g., Chernobil), medical and other occupational errors

- RAND estimates large economic losses due to sleep deprivation
  - US: 2.28% of GDP
  - Japan: 2.92% of GDP
Sleep Matters: Firms, Army, Teams Know it!

Employers realize the negative effects on productivity
- Cyberloafing increases on the day after the start of DST
- Virgin increased schedule flexibility and smart working policies
- U.S. Army Performance Triad: sleep, diet and physical fitness.
Sleep Matters: Firms, Army, Teams Know it!

Employers realize the negative effects on productivity
- Cyberloafing increases on the day after the start of DST
- Virgin increased schedule flexibility and smart working policies
- U.S. Army Performance Triad: sleep, diet and physical fitness.
- **Aetna pays employees to sleep more**
  - If they can prove they get 20 nights of sleep for seven hours or more in a row, they get $25 a night, up to $500 a year
  - Various ways to help workers keep track, including the use of Fitbit fitness trackers
Sleep Matters: Firms, Army, Teams Know it!

Employers realize the negative effects on productivity

- Cyberloafing increases on the day after the start of DST
- Virgin increased schedule flexibility and smart working policies
- U.S. Army Performance Triad: sleep, diet and physical fitness.
- Aetna pays employees to sleep more
  - If they can prove they get 20 nights of sleep for seven hours or more in a row, they get $25 a night, up to $500 a year
  - Various ways to help workers keep track, including the use of Fitbit fitness trackers

Recent quasi-experimental studies show consequences on:

- Health, Cognitive skills, Productivity
  (Heissel and Norris 2017; Gibson and Shrader, 2015; Giuntella & Mazzonna, 2015; Jin and Ziebarth, 2015)
Background

But, why the poor sleep? ⇒ Puzzling!

- Most assume optimal choices (Biddle and Hamermesh, 1990)
  - Individuals allocate time to more productive activities
- Yet, we often regret the previous night’s decision on bedtime
  - Was staying up late worth the morning sleepiness?
- Although we have immediate feedback ...
  - Costs are felt when you hit the Snooze button
- And frequent feedback
  - We still don’t learn
Background

But, why the poor sleep? ⇒ Puzzling!

- Most assume optimal choices (Biddle and Hamermesh, 1990)
  - Individuals allocate time to more productive activities
- Yet, we often regret the previous night’s decision on bedtime
  - Was staying up late worth the morning sleepiness?
- Although we have immediate feedback ...
  - Costs are felt when you hit the Snooze button
- And frequent feedback
  - We still don’t learn

Sendhil Mullanaithan (NYT, 2014):

“Sleep deserves serious study by behavioral economists”
Background

What can influence sleep quality?
Background

What can influence sleep quality?
- Environment: temperature, light, bed, pillow, etc.
- Health condition
- Work or family duties
- Emotional state
Background

What can influence sleep quality?

- Environment: temperature, light, bed, pillow, etc.
- Health condition
- Work or family duties
- Emotional state
- We focus on **Bedtime**
Our Contribution

Broader research agenda:
- Shed light on the mechanisms behind poor sleep-related choices
- Identify interventions that may nudge people into healthier sleep

Today: Focus on monetary incentives
- Do individuals respond to incentives to sleep earlier/longer?
- Are these incentives effective to improve health and human capital?

Some evidence on potential behavioral mechanisms:
- Biased belief
- Risk attitude
- Self-serving bias
- Present bias
Mechanisms

- Rational Model
  - Time should be allocated efficiently
- Biased belief
  - Underestimation of the risks of bad sleep habits
- Risk attitude
  - Risk seeking in the health domain
- Self-serving bias
  - Bad things won’t happen to me
- Present bias
  - Enjoy immediate gratification
  - Naïvete and Sophistication
Experimental Setting

1st/2nd/3rd round: 200 subjects
- Oxford University
- Oxford Brookes University

4th round: 100 subjects
- University of Pittsburgh

Experiment duration: 8 weeks
- Follow-up surveys (3 and 6 months after)

Student subjects: relatively homogeneous
- 62% male, average age 21.9.
- 10% report poor health; average BMI 24; 3% obesity.
- 21% were smokers, 60% quit; 30% drink more than once a week.
Experimental Design

[Diagram showing a timeline for Recruit, Lab Sessions, and Surveys and Treatments, spanning from Week 0 to Week 8.]

Avery, Giuntella & Jiao, 2018
Experimental Design: Day 1 Lab Session

A unique ID number for each subject, linking subject to Fitbit data.

Avery, Giuntella & Jiao, 2018
After the survey, we provided information:

**Insufficient sleep**

- Associated with a number of chronic diseases and conditions, such as diabetes, cardiovascular disease, obesity, and depression, which threaten our nation’s health.
- Responsible for motor vehicle and machinery-related crashes, causing substantial injury and disability each year.

**Sleeping too late**

- According to researchers in Japan, participants in a study who went to bed after midnight were found to have significantly more arterial stiffening (an early sign of heart disease).
- You may pride yourself on burning the midnight oil, but studies have shown that night-owl habits can actually lead to insomnia.
- People who stay up late tend to eat late, and eat even when they’re not hungry. The body stores (instead of burns!) calories taken in from late-night snack fests.
Experimental Design

3 months after experiment:
- Follow up survey on time use, sleep, and health
- Self-reported academic performance (before and after experiment)
Fitness Trackers: Fitbit

- All subjects received a Fitbit Charge HR during the lab session
- Subjects synced their data on safe platform (Fitabase)
- We got the data feed safely and anonymously
- Fitbit data were collected for 8 weeks
Fitness Trackers: Fitbit

- All subjects received a Fitbit Charge HR during the lab session
- Subjects synced their data on safe platform (Fitabase)
- We got the data feed safely and anonymously
- Fitbit data were collected for 8 weeks

*Why Fitbits? Are Fitbits reliable?*
Sleep Measured in the Lab: Polysomnography (PSG)
Or Measured by Fitbit
Measurement: Fitbit vs PSG
Fitbit vs Other Sleep Trackers

We use Fitbit Charge HR

- Charge HR does as well as Actigraphy
  - Charge HR showed high accuracy of sleep evaluation and circadian rest-activity rhythm measurement (Lee et al. 2017)

- And Fitbit is more widely used:
  - Actigraphy: A commonly used device in sleep research
  - But Actigraphy is more bulky and less user friendly

- Rich information on sleep, activity, movement, heart rate
Fitbit Data

Sleep (minutes-logs)
- Duration
- Quality

Physical Activity (minutes-logs)
- Number of Steps, Floors
- Minutes of Intense Physical Activity (Moderate, Vigorous etc.)
  - Based on Heart Rate

Heart Rate
- Resting heart rate (daily)
- Heart Rate Beat (minutes-logs)
Sleep

Avery, Giuntella & Jiao, 2018

7 h 15 mins asleep

- Awake for 1 mins (1x)
- Restless for 10 mins (4x)

Friday, December 6
Heart Rate

Avery, Giuntella & Jiao, 2018

Incentives to Sleep
Steps

DATA INSIGHTS
12/12/2012 - 12/19/2012

Average
Steps: 9,047

High
Steps: 15,575 (12/13/2012)

Low
Steps: 2,886 (12/19/2012)

Avery, Giuntella & Jiao, 2018

Incentives to Sleep 22 / 52
Week 1 Results: Before treatment
Are Students Sleep-Deprived?

Sleep Duration

- Oxford
- Pittsburgh
Week 1 Results: Before treatment

Men and women?

Sleep Duration by Gender

Avery, Giuntella & Jiao, 2018
Week 1 Results: Before treatment

![Bar chart showing sleep duration for different categories: sleep less than 5, sleep less than 6, sleep less than 7, and sleep less than 8. The categories with sleep less than 8 have the highest frequency.](image)
Week 1 Results

Sleep less than 7 hours

Sunday: 0.45
Monday: 0.45
Tuesday: 0.5
Wednesday: 0.4
Thursday: 0.45
Friday: 0.35
Saturday: 0.35

Avery, Giuntella & Jiao, 2018
Week 1 Results

- Subjects sleep on average 7 hours and 15 minutes;
- Women sleep 15 minutes longer on average;
- 43% slept less than 7 hours, 20% less than 6 hours;
- 97% consider it ideal to sleep more than 7 hours.
## Week 1 Results

Correlation between sleep, health and well-being

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>good_health</th>
<th>obese</th>
<th>overweight</th>
<th>depressed</th>
<th>satisfied</th>
</tr>
</thead>
<tbody>
<tr>
<td>sleep less than 7hrs</td>
<td>-0.1837***</td>
<td>0.0262</td>
<td>0.1047*</td>
<td>0.1619**</td>
<td>-0.2190***</td>
</tr>
<tr>
<td></td>
<td>(0.059)</td>
<td>(0.024)</td>
<td>(0.055)</td>
<td>(0.064)</td>
<td>(0.063)</td>
</tr>
<tr>
<td>Observations</td>
<td>243</td>
<td>237</td>
<td>237</td>
<td>243</td>
<td>243</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.038</td>
<td>0.005</td>
<td>0.015</td>
<td>0.026</td>
<td>0.047</td>
</tr>
<tr>
<td>Mean of Dep. Var.</td>
<td>0.679</td>
<td>0.0338</td>
<td>0.232</td>
<td>0.560</td>
<td>0.510</td>
</tr>
<tr>
<td>Std.Dev. of Dep. Var.</td>
<td>0.468</td>
<td>0.181</td>
<td>0.423</td>
<td>0.497</td>
<td>0.501</td>
</tr>
</tbody>
</table>

| 7 ≤ sleep ≤ 9          | 0.2056***   | -0.0249| -0.1134**  | -0.1426** | 0.2185*** |
|                        | (0.059)     | (0.024)| (0.055)    | (0.064)   | (0.063)   |
| Observations           | 243         | 237   | 237        | 243       | 243       |
| R-squared              | 0.048       | 0.005 | 0.018      | 0.020     | 0.047     |
| Mean of Dep. Var.      | 0.679       | 0.0338| 0.232      | 0.560     | 0.510     |
| Std.Dev. of Dep. Var.  | 0.468       | 0.181 | 0.423      | 0.497     | 0.501     |
Week 1 Results

Associations:
- Insufficient sleep associated with ↑ BMI
  - Sleeping < 7hrs: associated with a 25% ↑ overweight status
  - Sleeping < 7hrs: twice as likely to report obese status
- Insufficient sleep associated with ↓ CRT

Self-serving bias:
- People predict lower sleep-related risk for self than for others
  - ⇒ 12.5% ↑ insufficient sleep
- People predict better sleep quality for self than for others
## Experimental Design: Treatments

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Wave</th>
<th>Location</th>
<th>Time</th>
<th>Incentive</th>
<th>Prediction Reward</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>1</td>
<td>Oxford</td>
<td>Oct-Dec 2016</td>
<td>None</td>
<td>No</td>
</tr>
<tr>
<td>BW-WK</td>
<td>1</td>
<td>Oxford</td>
<td>Oct-Dec 2016</td>
<td>Biweekly, Weak</td>
<td>No</td>
</tr>
<tr>
<td>W-SG-P1</td>
<td>2</td>
<td>Oxford</td>
<td>Apr-Jun 2017</td>
<td>Weekly, Strong</td>
<td>Yes, 1</td>
</tr>
<tr>
<td>W-SG-P3</td>
<td>3</td>
<td>Oxford</td>
<td>Oct-Dec 2017</td>
<td>Weekly, Strong</td>
<td>Yes, 3</td>
</tr>
<tr>
<td>BW-SG-P1</td>
<td>4</td>
<td>Pittsburgh</td>
<td>Jan-Mar 2018</td>
<td>Biweekly, Strong</td>
<td>Yes, 1</td>
</tr>
</tbody>
</table>
Experimental Design

Three types of surveys
- **Survey with No Sleep Incentive (Survey)**
  - Sleep and health in past week
  - Cognitive reflection task
- **Survey with Sleep Incentive (Survey+SI)**
  - Same as Survey above
  - Sleepiness when answering the survey
    - Choose bedtime target (10 pm ∼ 1 am) and duration target (7 ∼ 9 hrs)
    - For Monday to Thursday nights of the week
    - Choose between 2 contracts
      - 1 Reward for each night achieved
      - 2 Same Reward for each night achieved; Punishment for failure
- **Time Use Diary (TUD)**
  - Recall what they did in half-hour intervals during previous day
  - Multiple choice questions

Avery, Giuntella & Jiao, 2018
Experimental Design

Three types of surveys

- **Survey with No Sleep Incentive (Survey)**
  - Sleep and health in past week
  - Cognitive reflection task

- **Survey with Sleep Incentive (Survey+SI)**
  - Same as Survey above
  - Sleepiness when answering the survey
  - Choose bedtime target (10 pm ~ 1 am) and duration target (7 ~ 9 hrs)
  - For Monday to Thursday nights of the week
  - Choose between 2 contracts
    1. Reward for each night achieved
    2. Same Reward for each night achieved; Punishment for failure
  - Predict achievement rates: £2 for a randomly chosen prediction
Experimental Design

Three types of surveys

- **Survey with No Sleep Incentive (Survey)**
  - Sleep and health in past week
  - Cognitive reflection task

- **Survey with Sleep Incentive (Survey+SI)**
  - Same as Survey above
  - Sleepiness when answering the survey
  - Choose bedtime target (10 pm ~ 1 am) and duration target (7 ~ 9 hrs)
  - For Monday to Thursday nights of the week
  - Choose between 2 contracts
    1. Reward for each night achieved
    2. Same Reward for each night achieved; Punishment for failure
  - Predict achievement rates: £2 for a randomly chosen prediction

- **Time Use Diary (TUD)**
  - Recall what they did in half-hour intervals during previous day
  - Multiple choice questions
Incentives

- First day lab session: show up fee £4
  + reward according to risk-time preference choices.
- Upon returning the device: £10
  + the chance to enter a lottery to win £100.
- WEAK: No endowment;
  £2.5 reward, £2 punishment.
- STRONG: Endowed with £10 each week;
  £2.5 reward, £2.5 punishment.
Bedtime Targets

![Bar chart showing the percentage of nights on which bedtime target was achieved for BW-WK and W-SG groups.](chart.png)
Treated Subjects Slept Earlier!
**Treated Subjects Slept Longer!**

**Table: Incentives and Sleep (W-SG)**

<table>
<thead>
<tr>
<th>Dep. Var.</th>
<th>(1) $7 \leq \text{SleepHours} \leq 9$</th>
<th>(2) $7 \leq \text{SleepHours} \leq 9$</th>
<th>(3) $7 \leq \text{SleepHours} \leq 9$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment weeks</td>
<td>0.069**</td>
<td>0.050*</td>
<td>0.073**</td>
</tr>
<tr>
<td></td>
<td>(0.031)</td>
<td>(0.030)</td>
<td>(0.033)</td>
</tr>
<tr>
<td>Post-treatment</td>
<td></td>
<td></td>
<td>0.033</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.034)</td>
</tr>
<tr>
<td>Observations</td>
<td>1,496</td>
<td>1,496</td>
<td>1,496</td>
</tr>
<tr>
<td>Individual F.E.</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Mean of Dep. Var.</td>
<td>0.49</td>
<td>0.49</td>
<td>0.49</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
</tr>
</tbody>
</table>

Notes: All estimates include controls for gender, a quadratic in age, week dummies and day of the week dummies. Robust standard errors are reported in parentheses.
Treated subjects are less likely to sleep less than 7 hours.

<table>
<thead>
<tr>
<th>Dep. Var.</th>
<th>(1) Sleep &lt; 7 hours</th>
<th>(2) Sleep &lt; 7 hours</th>
<th>(3) Sleep &lt; 7 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment weeks</td>
<td>-0.069**</td>
<td>-0.038</td>
<td>-0.066*</td>
</tr>
<tr>
<td>Post-treatment</td>
<td></td>
<td>-0.016</td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>1,496</td>
<td>1,496</td>
<td>1,496</td>
</tr>
<tr>
<td>Individual F.E.</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Mean of Dep. Var.</td>
<td>0.43</td>
<td>0.43</td>
<td>0.43</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>0.49</td>
<td>0.49</td>
<td>0.49</td>
</tr>
</tbody>
</table>

Notes: All estimates include controls for gender, a quadratic in age, week dummies and day of the week dummies. Robust standard errors are reported in parentheses.
Size and frequency of incentive matter

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>7 hours &lt; sleep &lt; 9 hours</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Panel A</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weak Incentive</td>
<td>0.0212</td>
<td>0.0185</td>
<td>0.0216</td>
<td>0.0206</td>
</tr>
<tr>
<td></td>
<td>(0.050)</td>
<td>(0.042)</td>
<td>(0.051)</td>
<td>(0.040)</td>
</tr>
<tr>
<td>Post Weak Incentive</td>
<td></td>
<td></td>
<td>0.007</td>
<td>0.0162</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.064)</td>
<td>(0.056)</td>
</tr>
<tr>
<td>Mean</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Observations</td>
<td>1,911</td>
<td>1,911</td>
<td>1,911</td>
<td>1,911</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>7 hours &lt; sleep &lt; 9 hours</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Panel B</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strong Incentive</td>
<td>0.0667***</td>
<td>0.0507***</td>
<td>0.0787***</td>
<td>0.0519***</td>
</tr>
<tr>
<td></td>
<td>(0.017)</td>
<td>(0.017)</td>
<td>(0.018)</td>
<td>(0.017)</td>
</tr>
<tr>
<td>Post Strong Incentive</td>
<td></td>
<td></td>
<td>0.0348*</td>
<td>0.00347</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.021)</td>
<td>(0.020)</td>
</tr>
<tr>
<td>Mean</td>
<td>0.46</td>
<td>0.46</td>
<td>0.46</td>
<td>0.46</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Observations</td>
<td>5,011</td>
<td>5,011</td>
<td>5,011</td>
<td>5,011</td>
</tr>
<tr>
<td>Individual FE</td>
<td>Yes</td>
<td></td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>
Size and frequency of incentive matter

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weak Bi-weekly Incentive</td>
<td>0.0216</td>
<td>0.0206</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0506)</td>
<td>(0.0400)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strong Weekly Incentive</td>
<td></td>
<td></td>
<td>0.112***</td>
<td>0.0629***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.0258)</td>
<td>(0.0238)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strong Bi-weekly Incentive</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.0394</td>
<td>0.0346</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.0250)</td>
<td>(0.0238)</td>
</tr>
<tr>
<td>Post Weak Bi-weekly Incent</td>
<td>0.00700</td>
<td>0.0162</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0636)</td>
<td>(0.0558)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post Strong Weekly Incent</td>
<td></td>
<td></td>
<td>0.0576**</td>
<td>0.00574</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.0263)</td>
<td>(0.0241)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post Strong Bi-weekly Incent</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.000494</td>
<td>0.00579</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.0364)</td>
<td>(0.0367)</td>
</tr>
<tr>
<td>N</td>
<td>1911</td>
<td>1911</td>
<td>2742</td>
<td>2742</td>
<td>2269</td>
<td>2269</td>
</tr>
</tbody>
</table>
Present Bias?

- Sophisticated hyperbolic discounter prefers commitment device.
- Naïve hyperbolic discounter is indifferent.
- Therefore, preference for commitment device is weakly associated with sophisticated hyperbolic discounting, or present bias.
Preference for commitment device

More than 35% of subjects chose dominated targets

- More than 35% of subjects chose dominated targets
Preference for commitment device

More than 35% of subjects chose dominated targets
And 10% of subjects chose dominated contracts
## Table: Sleep and Bedtime Commitment

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>(1) $7 \leq \text{SleepHours} \leq 9$</th>
<th>(2) Sleep $&lt; 7$ hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target before 1am (in treatment weeks)</td>
<td>0.173*** (0.040)</td>
<td>-0.129*** (0.039)</td>
</tr>
<tr>
<td>Observations</td>
<td>1,496</td>
<td>1,496</td>
</tr>
<tr>
<td>Individual F.E.</td>
<td>YES</td>
<td>YES</td>
</tr>
</tbody>
</table>

Notes: All estimates include controls for gender, a quadratic in age, week dummies and day of the week dummies. Robust standard errors are reported in parentheses.
Predictions

Overoptimism: 63% in Week1, 57% in Week2, 68% in Week3

<table>
<thead>
<tr>
<th>Prediction (all)</th>
<th>In</th>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>For</td>
<td>Week 1</td>
<td>2.89</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Week 2</td>
<td>2.83</td>
<td>2.70</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Week 3</td>
<td>2.94</td>
<td>2.71</td>
<td>2.58</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Achievement (all)</th>
<th>In</th>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Week 1</td>
<td>1.89</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Week 2</td>
<td>1.89</td>
<td>1.84</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Week 3</td>
<td>1.89</td>
<td>1.84</td>
<td>1.39</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pred-Ach (all)</th>
<th>In</th>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>For</td>
<td>Week 1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Week 2</td>
<td>0.94</td>
<td>0.86</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Week 3</td>
<td>1.05</td>
<td>0.87</td>
<td>1.19</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Count (All)</th>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>129</td>
<td>124</td>
<td>113</td>
</tr>
<tr>
<td></td>
<td>109</td>
<td>113</td>
<td>115</td>
</tr>
</tbody>
</table>

Avery, Giuntella & Jiao, 2018
Predictions and commitment device

Those who expect later bedtime chose earlier targets.
Estimated effects are similar when using time use diary data;

Subjects were not studying/working/exercising when they were supposed to sleep;

Under STRONG incentive, subjects were significantly less likely to report "surfing on the Internet".
Moreover, Treated Subjects Slept Better...

Sleep Efficiency measured by minutes asleep divided by minutes in bed.

<table>
<thead>
<tr>
<th>Table: Low Sleep Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Both vs Control</td>
</tr>
<tr>
<td>Treatment weeks</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Observations</td>
</tr>
<tr>
<td>R-squared</td>
</tr>
<tr>
<td>Individual F.E.</td>
</tr>
</tbody>
</table>

Notes: All estimates include controls for gender, a quadratic in age, week dummies and day of the week dummies. Robust standard errors are reported in parentheses.
...and Had More Regular Sleep Schedule!

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SD of Hours Slept</td>
<td>SD of Bedtime</td>
<td>SD of Wake Up Time</td>
</tr>
<tr>
<td>Weak Bi-Weekly</td>
<td>-0.196**</td>
<td>0.00158</td>
<td>0.0291</td>
</tr>
<tr>
<td></td>
<td>(0.0929)</td>
<td>(0.0777)</td>
<td>(0.100)</td>
</tr>
<tr>
<td>Strong Weekly</td>
<td>-0.324***</td>
<td>-0.132***</td>
<td>-0.243***</td>
</tr>
<tr>
<td></td>
<td>(0.0571)</td>
<td>(0.0468)</td>
<td>(0.0658)</td>
</tr>
<tr>
<td>Strong Bi-Weekly</td>
<td>-0.118**</td>
<td>-0.0588</td>
<td>0.117</td>
</tr>
<tr>
<td></td>
<td>(0.0537)</td>
<td>(0.0477)</td>
<td>(0.0843)</td>
</tr>
<tr>
<td>Post Weak Bi-Weekly</td>
<td>-0.0368</td>
<td>0.00317</td>
<td>0.0201</td>
</tr>
<tr>
<td></td>
<td>(0.230)</td>
<td>(0.125)</td>
<td>(0.179)</td>
</tr>
<tr>
<td>Post Strong Weekly</td>
<td>-0.108</td>
<td>0.0166</td>
<td>-0.170**</td>
</tr>
<tr>
<td></td>
<td>(0.0700)</td>
<td>(0.0527)</td>
<td>(0.0778)</td>
</tr>
<tr>
<td>Post Strong Bi-Weekly</td>
<td>-0.0105</td>
<td>0.0411</td>
<td>-0.0809</td>
</tr>
<tr>
<td></td>
<td>(0.0992)</td>
<td>(0.103)</td>
<td>(0.0754)</td>
</tr>
<tr>
<td>Mean</td>
<td>1.34</td>
<td>1.10</td>
<td>1.16</td>
</tr>
<tr>
<td>Standard Deviations</td>
<td>0.95</td>
<td>0.77</td>
<td>1.04</td>
</tr>
<tr>
<td>N</td>
<td>6795</td>
<td>6557</td>
<td>6557</td>
</tr>
<tr>
<td>R-sq</td>
<td>0.015</td>
<td>0.005</td>
<td>0.008</td>
</tr>
</tbody>
</table>
### Table: Effects on Health Outcomes

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Efficient Heart Rate</td>
<td>Heart Rate</td>
<td>at least 20 minutes</td>
<td>very active</td>
<td>sedentary minutes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Variability</td>
<td>moderate/vigorous</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(low resting heart rate)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>treated</td>
<td>0.076*</td>
<td>-0.195</td>
<td>0.073***</td>
<td>0.077***</td>
<td>-26.199***</td>
</tr>
<tr>
<td></td>
<td>(0.042)</td>
<td>(0.348)</td>
<td>(0.025)</td>
<td>(0.025)</td>
<td>(7.686)</td>
</tr>
<tr>
<td>Observations</td>
<td>1,845</td>
<td>1,859</td>
<td>4,332</td>
<td>4,332</td>
<td>4,319</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.050</td>
<td>0.055</td>
<td>0.011</td>
<td>0.011</td>
<td>0.025</td>
</tr>
</tbody>
</table>

**Panel A: Cross-sectional Analysis**

| treated | 0.060** | -0.173 | 0.033 | 0.032 | -17.239** |
|         | (0.028) | (0.288) | (0.024) | (0.024) | (8.002) |
| Individual Fixed Effects | YES | YES | YES | YES | YES |
| Observations | 1,845 | 1,859 | 4,341 | 4,341 | 4,328 |
| R-squared | 0.034 | 0.013 | 0.010 | 0.010 | 0.026 |

**Panel B: Within-Subject Analysis**

Notes: All estimates include controls for day of the week dummies. Cross-sectional analysis include controls for gender, and a quadratic in age. Robust standard errors are reported in parentheses.
Outcomes: Academic Performance

Avery, Giuntella & Jiao, 2018

Incentives to Sleep

Change in class percentile (academic performance)

- Control
- W-LG
- BW-WK
Outcomes: Academic Performance

- Green bar: Sleep at least 7hrs on most nights
- Red bar: Sleep less than 7hrs on most nights

Change in average percentile in class
### Potential Mechanisms

<table>
<thead>
<tr>
<th></th>
<th>(1) Sleep less than 7hrs</th>
<th>(2) Target met</th>
<th>(3) Target &lt; 1 am</th>
<th>(4) Sleep less than 7hrs</th>
<th>(5) Target met</th>
<th>(6) Target &lt; 1 am</th>
<th>(7) Sleep less than 7hrs</th>
<th>(8) Target met</th>
<th>(9) Target &lt; 1 am</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk Aversion</td>
<td>-0.00722 (0.0403)</td>
<td>0.0389 (0.0547)</td>
<td>-0.145 (0.0884)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present Bias</td>
<td>-0.0465 (0.0369)</td>
<td>0.148*** (0.0447)</td>
<td>0.105 (0.0756)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impatience</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.0196 (0.0419)</td>
<td>-0.0743 (0.0479)</td>
<td>0.201*** (0.0724)</td>
</tr>
<tr>
<td>N</td>
<td>2340</td>
<td>1545</td>
<td>1664</td>
<td>2340</td>
<td>1545</td>
<td>1664</td>
<td>2340</td>
<td>1545</td>
<td>1664</td>
</tr>
<tr>
<td>R-sq</td>
<td>0.011</td>
<td>0.022</td>
<td>0.064</td>
<td>0.012</td>
<td>0.039</td>
<td>0.060</td>
<td>0.011</td>
<td>0.026</td>
<td>0.083</td>
</tr>
</tbody>
</table>
Summary of Preliminary Findings

Individual sleep responds to monetary incentives

- Treated subjects slept earlier, longer, and better!

Evidence of sophisticated hyperbolic discounting

- 30-40% of subjects chose a dominated target
- 10% of subjects chose dominated contract

Evidence of self-serving bias

- Most subjects overestimate own sleep quality
- Over(under)estimating own sleep quality (risk) associated with shorter sleep duration

Treated subjects reported

- More efficient heart rate
- More intensive activities
- Improved academic performance (*but caution as attrition in follow-up*)
We are currently conducting more sessions...