SLEEP & CIRCADIAN RHYTHMS

PSYCH 106
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What is Sleep?

You spend 1/3 of your life asleep…

Originally thought of as a:

- **passive** state of immobility with
  - cessation of brain activity
  - lack of perception and consciousness

Now we know:

- sleep is composed of **different** states of **brain activity** (sleep stages)
- some perception – wake up faster in response to your own name than the names of others  
  (Oswald, Taylor & Treisman, 1960)
How do we measure sleep?

Polysomnography – gold standard in sleep measurement

- Electroencephalogram (EEG)
  - Records “brainwaves” – sum of electrical activity over an area of cortex

- Electrooculogram (EOG)
  - Records eye movements during sleep

- Electromyogram (EMG)
  - Detects activity in neck muscles during sleep
How do we measure sleep?

**WAKE**

- EEG

**Stages 1-4 (NREM)**

- EEG

**Rapid Eye Movement (REM)**

- EEG

- EOG

- EMG
Sleep stages across a sleep cycle

- REM = Rapid Eye Movements & dreaming
- Stages 1 & 2 of NREM = “light” sleep
- Stages 3 & 4 of NREM = “deep” Slow Wave Sleep
- Sleep cycle = ~ 90 min
Deep, Slow-wave Sleep (SWS) is mostly observed at the beginning of the night.

REM sleep is mostly observed at the end of the night (last 2-3 cycles).

Sleep stages across the night
Sleep across life

How much sleep do you really need?

- **Newborn to 2 months old**: 12 hrs to 18 hrs
- **3 months to 1 year old**: 14 hrs to 15 hrs
- **1 to 3 years old**: 12 hrs to 14 hrs
- **3 to 5 years old**: 11 hrs to 13 hrs
- **5 to 12 years old**: 10 hrs to 11 hrs
- **12 to 18 years old**: 8.5 hrs to 9.25 hrs
- **Adult (18+)**: 7 hrs to 9 hrs

(National Sleep Foundation; whydon'tyoutrythis.com)
Sleep disorders

- **Insomnia**
  - Inability to fall or stay asleep

- **Sleep Apnea**
  - Stop breathing during the night, leads to repeated awakenings
  - Most commonly seen in males, overweight, and elderly

- **Narcolepsy**
  - “sleep attacks:” subjects enter directly in REM sleep

- **REM sleep disorder**
  - Acting out dreams

- **Sleepwalking, talking, and night terrors** occur mostly in slow-wave sleep
Sleep affects…

- **Cognitive performance**
  - Alertness, attention, reaction time
  - Decision-making
  - Memory

- **Psychological health**
  - Mood
  - Depression, anxiety

- **Physiological health**
  - Growth hormone production
  - Rest and restoration
  - Healing and regeneration of bones, muscles and other tissues
  - Immune function
  - Metabolism

- and much more…
Sleep & cognition

- 24 h of sleep deprivation = 0.1 BAC
- ~16-60% of all car accidents due to sleep deprivation
- Sleep debt is cumulative – sleeping for only 6 h/night for 2 weeks = same deficits as 24 h sleep deprivation
- Mismatch between perception and performance (people think they’re OK)
- Adding sleep (napping) improves memory
Sleep & cognition

- Sleep is related to GPA:

  How **much** you sleep…

  ![Bar chart showing GPA by amount of sleep](image1)

  (2007 UC Berkeley Office of Student Research)

  How **consistent** your sleep is…

  ![Scatter plot showing GPA vs. sleep regularity index](image2)

  2017 study of Harvard students [Phillips et al., 2017]
Sleep in college
Sleep in college

On how many days of the past 7 days did you get enough sleep so that you felt rested when you woke up in the morning?

The 2010 National College Health Assessment by the American College Health Association
Sleep in adolescence

Teens get less & less sleep as they progress through highschool...

2000 National Sleep Foundation report
Class time is typically close to 7:15am so highschoolers wake around 6am

Two schools changed start time from 7:20 to 8:00am

Students got 45 min more sleep on school days

Those extra 45 min of sleep…
- Better grades & SAT scores
- ½ daytime sleepiness
- Fewer doctor visits/late/absent
- Better mood

*data from Owens, Belon & Moss, 2010*
Sleep in adolescence

![Graph showing sleep patterns in adolescence]

*Total Sleep Time:*
- 7-7.49
- 7.5-7.99
- 8-8.49
- 8.5-8.99
- 9-9.49
- 9.5-9.99
- 10-10.49 hrs

*Restricted Wake Time*
Based on preferences for sleep/wake timing and reported alertness across the day

- Genetic component – runs in families
- Associated with the timing of melatonin, cortisol, & BT rhythms
- Changes with age
  - Early -> Late -> Early
What are Circadian Rhythms?
Many aspects of your physiology & behavior have circadian rhythms.

“circa” = about
“dia” = day
Circadian rhythms and behavior

Figure adapted from Froy, 2012 and Glickman, 2013
Some of your body’s circadian rhythms…

- Highest testosterone secretion: 09:00
- Melatonin secretion stops: 07:30
- Sharpest rise in blood pressure: 06:45
- Deepest sleep: 02:00
- Noon: 12:00
- Best coordination: 14:30
- Fastest reaction time: 15:30
- Greatest cardiovascular efficiency and muscle strength: 17:00
- 18:00
- 18:30 Highest blood pressure
- 19:00 Highest body temperature
- 21:00 Melatonin secretion starts
- Midnight: 00:00
- Lowest body temperature: 04:30
Even behaviors have a rhythm...

- Most emotional tweets
- Most upbeat tweets
- Most emails read
- Most “likes” on Facebook
- Most tweets re-tweeted
- Most Twitter usage
- Most Facebook usage
- Most people check their phone for the first time
- Least Twitter usage
- Least Facebook usage
- Most “likes” on Facebook
- Most emotional tweets
- Midnight
- Noon
The Two-Process Model of Sleep
Shifting your clock

20 Days

Different rates:
Liver in London
Brain in Baltimore
Heart in San Francisco

24 h

Figure adapted from Harrison & Gorman, 2015 and Glickman, 2013
Circadian disruption

The circadian system has a slow adjustment rate of ~1 h/day

When your schedule changes….

- Daylight savings
  - ± 1 hr
- Travel across time zones
  - East coast +3 hr
- Shiftwork
  - work at night or on a schedule that changes frequently
- Undergrad class schedules 😞
Circadian disruption in shiftwork

- The circadian system has a slow adjustment rate of a little more than 1 h/day

- 15 million individuals work outside regular 9-5 shift (U.S. Department of Labor)

- Increased risk of accident & injury (Folkard & Tucker, 2003)

- Myriad physiological & psychological consequences (Evans et al. 2013; Brown et al., 2009; Lawson et al., 2011)

- WHO has cited night shiftwork as a probable carcinogen

- Compromised alertness, performance and health cost ~$200 billion annually (Kerin & Aguirre, 2005)

- Limited practical solutions
What causes the harm?

Three interconnected processes interact in the shiftworker:

- Sleep deprivation
- Circadian misalignment – doing things at the wrong time (jet-lag symptoms, eating, sleeping, concentrating etc)
- Light at night
The visual system

- Two types of photoreceptors for vision:
  - **Cones**: color, daytime and detail vision (5-10%)
  - **Rods**: dim light (90-95%)
    - **Both** send impulses toward the center of the eye
  - **Ganglion cells** carry visual info to the brain via their axons (optic nerve)
Non-visual responses to light

What about non-image forming responses to light? *Alertness, pupillary light reflex, shifting circadian rhythms, melatonin suppression*

Mediated by rods and cones?

...effects persist even in blind individuals
Melatonin Suppression Action Spectrum

$\lambda_{\text{max}} = 464$ nm
$R^2 = 0.91$

Brainard et al., 2001
# ACTION SPECTRA
for non-image forming functions

<table>
<thead>
<tr>
<th>Peak $\lambda$</th>
<th>Species</th>
<th>Response</th>
<th>Author, Year</th>
</tr>
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<tbody>
<tr>
<td>459</td>
<td>Human</td>
<td>Melatonin Suppression</td>
<td>Thapan, et al., 2001</td>
</tr>
<tr>
<td>479</td>
<td>Mouse</td>
<td>Pupillary Light Reflex</td>
<td>Lucas, et al., 2001</td>
</tr>
<tr>
<td>481</td>
<td>Mouse</td>
<td>Circadian Phase-Shifting</td>
<td>Hattar, et al., 2003</td>
</tr>
</tbody>
</table>

Non-image forming functions all have peak sensitivity in 460-480 range (different than rods and cones)
Intrinsically photosensitive Retinal Ganglion Cells (ipRGCs)

- A subset of Retinal Ganglion cells (approx. 2%)
  - Are intrinsically photoreceptive
  - Contain the photopigment melanopsin

- Same neural pathway as vision?
Light & Visual system

- Light
- Signal

Diagram showing the visual system with pathways from light to visual cortex.
Light & Circadian system

Retinohypothalamic Tract (RHT)

SCN
Suprachiasmatic Nucleus

www.skidmore.edu/~hfoley/Perc3.htm
www.cs.brown.edu/~deus/courses/optical/Contrast3
Light at night
Increased technology is not only distracting, but *light at night*:

- **Shifts your clock** (< 20 min of low room light enough)
  - keeping your light on for 1 extra hour = flying 1 hour westward (jet lag!)
- significantly **suppresses melatonin**, your “nighttime” hormone
- increases feelings of **alertness**
Thank you!

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