Measuring sleep and sleepiness with mobile devices

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Why measure sleep?

- Memory
- Decision-making
- Stress management
- Clean ‘brain waste’
- Emotion regulation
- Immune function
Why measure sleep?

Sleep

- Aging
- Social/economic factors
- Parenting
- Psychological disorders
- Adolescents
- Neurodegenerative diseases
- Memory
- Decision-making
- Stress management
- Clean ‘brain waste’
- Emotion regulation
- Immune function

Aging

Social/economic factors

Parenting

Psychological disorders

Adolescents

Neurodegenerative diseases

Memory

Decision-making

Stress management

Clean ‘brain waste’

Emotion regulation

Immune function
Sleep is treatable behaviorally

- Drugs
- Sleep Hygiene

Pre- vs. Post-

Wake after sleep onset (mins)

e.g., Jacobs et al., Arch Int Med, 2004
McClusky et al., Am J Psychiatry, 1991
WAKE
nREM1
REM
nREM2
SWS

11:00  1:00  3:00  5:00

nREM1 - transitional sleep stage
SWS - memory consolidation - glymphatic function
REM - emotion regulation - creativity and decision making
nREM2 - plasticity - particularly motor learning
Key points
• Sleep is not homogenous and all stages serve a unique function
• SWS may be particularly essential in neurodegenerative diseases given the role in glymphatic clearing
Key features of sleep that impact quality of life

Sleep quantity

more sleep, more of all of these functions

Sleep quality

less time wasted awake in bed improves function

Sleep sufficiency

Does it meet sleep need?
Sleep measurement

EEG
EOG
EMG
Polysomnography

Actiwatch Spectrum (Respironics)
Non-dominant wrist

Actiwatch
Portable amplifier
IALS Center for Personalized Health Monitoring

Sample recordings

Week 1

Week 2
Sample recordings

- Sleep onset
- Slow wave sleep
- Night waking
- REM
- Wake
Polysomnography

Take home message:
• EEG is necessary to identify sleep
• EMG/EOG is necessary to identify sleep stages
Polysomnography

A montage:
- EEG (electroencephalography)
- EOG (electroculography)
- EMG (electromyography)

Can also have (for sleep disorder dx):
- Leg EMG
- Snore sensor
- ECG (electrocardiogram)
- Pulse oximetry
- Plethysmography
Key features of sleep that impact quality of life

BMD proxy for sleep quantity

*Sleep period=time ‘in bed’
What is measured by devices?

Research-based actigraphs

ActiWatch (Philips Respironics) ~$800

ActiGraph ~$200
Actigraphy

- Contains triaxial accelerometer

- Provides an *estimate* of the sleep/wake cycle via movement (or absence of). Based on many assumptions.

- Summarizes the frequency of motions into epochs of specified time duration and stores the summary in memory
Actigraphy
Actigraphy – research-based actigraphs

Advantages:

- **Objective** (compared to questionnaires, observation)
- Can be worn over multiple days/weeks
- Correlation between actigraphy- and PSG-defined sleep estimates

Disadvantages

- Accuracy is lower for some groups
- Cannot score sleep architecture
- **Scoring data is tedious**
- Validated data requires simultaneous diary
Comparison of commercial BMDs

- Basis
- Misfit
- Fitbit (Flex)
- Research actigraph (Spectrum)
- Withings
Total Sleep Time
Sleep Efficiency (sleep score)
Deep & Light Sleep
Other current devices

- Smartphone apps
  - Sleep Cycle, Sleep Time, SleepBot, MotionX

- Beddit
Challenges – part 1

- Actigraphy-based sleep measures are *generally* reliable for total sleep time and sleep efficiency.
- However, most studies are:
  - Limited to healthy young adults
  - Focused on night-time (supine) sleep
  - Inactivity v. napping v. sleepiness mid-day is indistinguishable
- BMDs do not capture sleep stages accurately. Given that SWS may be key and nREM1 of limited use, total sleep time may not be enough.
- How to improve:
  - Portable polysomnography?
  - Actigraphy + (EEG, EMG)
## Commercial BMD usability

<table>
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<th>Feature</th>
<th>Fitbit</th>
<th>Misfit</th>
<th>Moov</th>
<th>Withings</th>
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<td>Battery length</td>
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<td>Auto-detect sleep</td>
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<td>Other</td>
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<td>Extreme work out feedback</td>
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</table>
Challenges – part 2

- Must limit opportunities to take it off
  - Battery life limits
  - Waterproof limitations

- Self-monitoring requires interpretable information
  - Is the ‘sleep score’ enough?

- What is the value of a sleep score without knowing how to change it?
Healthy sleep hygiene ‘s

ACTIVITY: Exercise!

ABN: Eliminate caffeine, evening light/stimulation

CONSISTENCY: Nap only if consistently; Bedtime +/- 1hr

MELATONIN & SUNLIGHT: Set your body clock

ENVIRONMENT: Quiet, cool, and dark room
Thanks.

Work by:
Nick Gravel
Janna Mantua
Thanks.

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