Methods for Assessing Sleep

- Simplest method: Questionnaires
  - Retrospective: past week, month, year, lifetime
  - Daily: Sleep diary
- What kinds of questions would you ask?
Common Questions About Sleep

- Did you nap during the day?
- Bed time and rise time → Time In Bed
- Time to fall asleep → Sleep Onset Latency
- Waking up during the night → Frequency of Night Awakenings and Wake After Sleep Onset
- Quality of Sleep
- Physical problems: breathing, pain, restlessness, temperature
- Use of alcohol or medication
# Sleep Diary

<table>
<thead>
<tr>
<th></th>
<th>First day</th>
<th>Second day</th>
<th>Third day</th>
<th>Fourth day</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Complete in morning</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bedtime (date/time)</td>
<td>10:45 p.m. (4/10)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rise time (date/time)</td>
<td>7:00 a.m. (4/11)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Estimated time to fall asleep</td>
<td>30 minutes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Estimated number of awakenings and total time awake</td>
<td>5 times 2 hours</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Estimated amount of sleep obtained</td>
<td>4 hours</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Complete at bedtime</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Naps (number, time, and duration)</td>
<td>1 at 3:30 p.m. 45 minutes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alcoholic drinks (number and time)</td>
<td>1 drink at 8:00 p.m. 2 drinks at 9:00 p.m.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>List stresses of the day</td>
<td>Flat tire</td>
<td>Argued with son</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rate how you felt today</td>
<td></td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>1 = Very tired/sleepy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 = Somewhat tired/sleepy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 = Fairly alert</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 = Wide awake</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irritability level</td>
<td></td>
<td></td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>1 = None</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 = Some</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 = Moderate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 = Fairly high</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 = High</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medications</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Observer Ratings

- Bed partner
- Roommate
- Nursing staff
- Sleep tech

http://3.bp.blogspot.com/_2TWdt7WJ_48/S96vqW_hNnl/AAAAAAAAAT8/NzHAt-8DLgc/s1600/funny-pictures-your-cat-watches-you-sleep.jpg
Actigraphy

- Small device worn on the wrist in adults
  - Accelerometer, light sensor (some models)
- Variable sampling rate: 15 seconds to 5 minutes, allowing recordings to range from days to months at a time

Standard Actigraphy Measures

- Sleep Onset Latency
- Time in Bed
- Total Sleep Time
- Number of Awakenings
- Wake After Sleep Onset
Actigraphy in Infants

- Actigraphs can be worn on infants’ ankles
- Sleep problems in infants at risk for depression can be detected at 2 weeks of age

Armitage et al., 2009
Polysomnography

- Traditional laboratory sleep study
- Simultaneous recording of multiple sleep-related physiological measures
What is all this stuff?
Polysomnography

- Three main measures:
  - EEG: electroencephalogram
  - EOG: electrooculogram
  - EMG: electromyogram
- These measures are used to determine different stages of sleep
- Additional measures used for detecting sleep disorders
EEG in Polysomnography

- Individual electrodes – NO CAPS
  - High likelihood of slipping during sleep
  - In waking EEG studies, subjects sit upright
  - In sleep studies, subjects have pillows and roll around
- EEG and EOG are recorded with references
  - Contralateral mastoid (or earlobe)
- Filters: usually 0.3-70 Hz
- Sampling: usually 256 Hz or faster

http://www.astro-medinc.com/electrode.jpg
EEG in Polysomnography

- Frontal (F3 and F4) for delta
- Central (C3 and C4) for Sleep Spindles and K Complexes
- Occipital (O1 and O2) for alpha

http://www.cnsforum.com/content/pictures/imagebank/hirespng/placement_EEG_leads.png
From before: our eyes are polarized
Eye movement generates electrical potentials
In waking EEG these are annoying artifacts
In polysomnography, these are helpful in distinguishing between stages of sleep
Placement of EOG electrodes

- Left Oculogram (LOC)
  - Below outer canthus
- Right Oculogram (ROC)
  - Above outer canthus
- Why?
  - When looking left or down, eyes move towards LOC and away from ROC
  - Opposite for looking right or up

Deflections are of opposite polarity, indicating eyes moving in the same direction.
EMG in Polysomnography

- In waking EMG, we want to know WHICH muscles are moving (e.g., corrugator, zygomatic) so we can infer emotion.
- In measuring sleep, we want to know the level of muscle tension that changes during sleep.
  - Best place to measure: under the chin.
What do we infer from alpha in wakefulness?
- Relaxation or inactivity
- A state in between wake and sleep

If alpha is in between wake and sleep, what do you think alpha during sleep represents?
- Increased arousal
- Again, a state in between wake and sleep
Sleep Stages

- **NREM: Non-Rapid Eye Movement Sleep**
  - N1: transition stage, less than 10% of sleep time
  - N2: about 50% of all sleep time
  - N3: also known as slow wave sleep or deep sleep, about 20% of sleep time

- **REM: Rapid Eye Movement sleep, about 20% of sleep time**

- **Non-sleep stages**
  - Awake
  - Movement time (too much artifact from movement to determine sleep stage)
Scoring Rules

- **Original rules:** Rechtschaffen and Kales, 1968
  - Before that, inconsistent definitions and terminology
- **New rules:** American Academy of Sleep Medicine, 2007
  - Slight revision of R & K
Overnight polysomnography can typically range from 6 to 10 hours.

Like in EEG analysis, we use epochs to break down the data into manageable pieces.

Typical epoch length is 30 seconds.

Each epoch is assigned a sleep stage.

- What is the majority of the epoch? 14.9 seconds of wake and 15.1 seconds of sleep means all 30 seconds are counted as sleep.
Criteria for Awake and N1

- **Awake**
  - EEG: high frequency, low amplitude activity
  - EOG: sharp eye movements
  - EMG: relatively high muscle tone, with increases related to movement

- **N1**
  - EEG: mixed frequency, low amplitude activity, less than 50% alpha
  - EOG: slow rolling eye movements
  - EMG: lower muscle tone than when awake
Transition from Wake to N1

Eye movements slow down

EEG changes: Alpha disappears

Rechtschaffen and Kales, 1968
Criteria for N2

- EEG: Sleep Spindles and/or K Complexes over a background of low amplitude, mixed frequency activity
  - Sleep Spindle: burst of 12-14 Hz activity 0.5 seconds or longer
  - K Complex: sharp negative inflection, followed by positive inflection and slow return to baseline, at least 75 microvolts amplitude and 0.5 seconds long

- EOG: generally no eye movements, but no specific criteria
- EMG: relatively low muscle tone
Absence of eye movements

Presence of sleep spindles and K complexes

K Complex

Sleep Spindle

Rechtschaffen and Kales, 1968
Criteria for N3

- EEG: greater than 20% of the epoch consists of high amplitude slow waves
  - High amplitude slow waves are >75 microvolts in amplitude and 0.5-2.0 Hz in frequency
- EOG: generally no eye movements, but no specific criteria
- EMG: relatively low muscle tone
EOG shows artifact from high amplitude EEG activity
Note that the deflections in LOC and ROC are in the same direction

High amplitude slow waves in EEG (underlined)

Rechtschaffen and Kales, 1968
Criteria for REM

- EEG: mixed frequency, low amplitude activity
  - ABSENCE of Sleep Spindles and K Complexes
- EOG: phasic bursts of rapid eye movements
- EMG: lowest muscle tone, almost complete inhibition of muscle activity
Rapid eye movements
Note opposite polarity in LOC and ROC

Low tonic EMG

Low amplitude, mixed frequency EEG

Sawtooth waves are also present (underlined), but are not required for REM
Hypnogram

- Sleep stages across the night are plotted to create a hypnogram
- This is a simple overview of a night’s sleep

Important Sleep Variables

- Sleep onset latency
- Sleep efficiency
- REM latency
- Percent of each sleep stage
- Number of awakenings
- Wake After Sleep Onset
Other Physiological Parameters

- Respiration
  - Respiratory effort with belts on ribcage and abdomen
  - Oral and nasal airflow with thermistor and pressure transducer
- Blood oxygen and pulse rate with pulse oximeter on finger
- Leg muscle activity with anterior tibialis EMG
- EKG (modified Lead II)
- Body position with sensor on belt and observation
Sleep Disorders

- Insomnia
  - Difficulty initiating sleep
  - Difficulty maintaining sleep
  - Early morning awakening
  - Nonrestorative sleep
- Multiple etiologies
  - Hyperarousal, learned behavior, secondary to another disorder, iatrogenic, poor sleep hygiene
- Multiple treatments
  - Drugs: proven short term, less evidence long term
  - Behavioral: proven in the short term AND long term!
Sleep Disorders

- Obstructive Sleep Apnea
  - Airway closes partially or entirely during sleep
  - Blood oxygen drops
  - Usually terminated by an arousal from sleep to resume breathing
  - Causes: being overweight (excess tissue), size and shape of airway, strength of airway muscles, inadequate innervation of airway muscles
  - Treatment: CPAP, which increases air pressure to hold airway open
Normal breathing during sleep

Obstructive sleep apnea

- Tongue
- Soft palate
- Uvula
- Blocked airway
Sleep Disorders

- Central Sleep Apnea: cessation of respiratory effort
  - Neurological or related to heart disease
- Periodic Limb Movement Disorder
  - Series of leg muscle twitches which can cause arousals from sleep
- Bruxism
  - Teeth grinding
  - Muscle activity can cause severe artifact in other channels
Bruxism
Moving Beyond Sleep Stages

- Sleep stages are nominal definitions
  - The main difference which holds up is the distinction between NREM and REM sleep
- A great deal of variability is ignored by sleep stages
- Divisions between N2 and N3 are arbitrary
  - Based solely on amount of high amplitude slow waves in an epoch
Where is the change from N2 to N3?

FIGURE 4

The top three tracings are Stage 2 and contain increasing percentages of high amplitude, slow wave activity but not enough to qualify for Stage 3. The tracings contain increasing percentages of high amplitude, slow wave activity and qualify as Stage 3. The tracings depict 20 sec epochs recorded on a Grass Model IV-C electroencephalograph with a paper speed of 15 mm/sec, a time constant of 0.3 sec and a calibration of 50 µV/cm.
Quantitative EEG Analysis

- Quantitative analysis of physiological data (especially EEG) can yield rich data.
- Instead of discussing N2 and N3, we can state exactly how much delta power was generated by a subject.
- We can analyze multiple frequency bands:
  - Delta: 0 to <4.0 Hz
  - Theta: 4.0 to <8.0 Hz
  - Alpha: 8.0 to <12.0 Hz
  - Sigma: 12.0 to <16.0 Hz
  - Beta: 16.0 Hz and above

NB: these frequency definitions vary between labs!
Types of Quantitative EEG Analysis

- **Fourier Transform** (frequency domain)
  - We have discussed this in waking EEG
  - In sleep, the computational technique is the same

- **Period Analysis** (time domain)
  - How often EEG signal crosses electrical baseline
  - How often there is a negative inflection in the EEG signal
  - Amplitude can also be calculated
Period Analysis

Zero cross is biased toward slow frequencies
First derivative (negative inflection) is biased toward faster frequencies

Hoffmann et al., 1979
Plotting Quantitative EEG Data

Power By Frequency

Power By Time

Landolt et al., 1996
Stage Scores and Quantitative Analysis

Power Spectral Analysis

Period Analysis
- less popular than FFT
- Blockiness is an artifact of the plotting program

Visually Scored Sleep Stages
- Universally reported
- Blockiness is inherent in the analysis

Figure 2. Comparison of delta (0.5 to <4 Hz) quantified by fast Fourier transforms (FFTs) (top), digital period analysis (DPA) (middle), and standard visual stage scoring (bottom).
Figure 5. Comparison of variables derived from PAA (upper left) and PSA (lower left) in the low delta band (0.1–2.1 Hz). Synchronized average curves over all subjects (N = 11). REM sleep episodes are indicated by interrupted vertical lines. The right panels are scatterplots of pairs of the 68 average values constituting the curves in the left panels. Linear regression lines are indicated. Upper panel (A2–A1): time in band (vertical axis) vs rectified amplitude (horizontal axis). Lower panel (B–A1): spectral amplitude (vertical axis) vs rectified amplitude (horizontal axis). The indicated correlation coefficients (\( \bar{r} \)) are averages over 11 individual correlation coefficients (N = 68).
What To Do With This Data?

- Compute power of frequency bands across entire night, or in particular stages (e.g., REM or NREM)
- Time course of delta power across the night

Brower et al., 2011
While the standard montage for sleep studies contains only 6 EEG leads, more can be added.

Full 10-20 EEG montage can and is used regularly for nocturnal seizure studies and more in depth quantitative analysis.
Changes in Theta Band During REM

After a learning task, theta power increases in frontal, central, parietal, and occipital leads

Fogel et al., 2007
Newer Methods

- These do NOT include measures of EEG 😞
- Home Sleep Apnea Testing
  - Respiratory channels
  - Pulse and blood oxygen
  - Body Position
- WatchPAT
  - Actigraphy
  - Pulse and blood oxygen
  - Peripheral Arterial Tone

http://www.kegohealthcare.ca/Products/Braebon_MediByte/Images1/MP8KN%20web%202.jpg

http://www.centerforsoundsleep.com/images/uars_watchPAT.jpg
Recapping Assessment Methods

- Questionnaires
- Observation
- Actigraphy
- Sleep Stage Scores
- Quantitative Analysis
Questions?

Special thanks to the faculty and staff of the University of Michigan Depression Center Sleep and Chronophysicsology Laboratory for giving me my start in the scientific study of sleep and Dr. Richard Bootzin for continuing it.

Roseanne Armitage, Ph.D., Director
Robert F. Hoffmann, Ph.D., Associate Director
J. Todd Arnedt, Ph.D.
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