Sleep, Memory, and Learning: What We All Need to Know

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What We Need to Know

- Sleep does not merely “cure sleepiness”
- Sleep is critical for psychiatric health
- Sleep is critical for emotional regulation
- Sleep is critical for understanding what we’ve learned
Sleep Doesn’t Just Cure Sleepiness

A Good Night’s Sleep
Sleep Physiology

Neuromodulation Varies Across the Wake-Sleep Cycle

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<th>Active Wake</th>
<th>Quiet Wake</th>
<th>SWS</th>
<th>REM</th>
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<tbody>
<tr>
<td>ACh</td>
<td>++</td>
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<td>−/+</td>
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<td>NE</td>
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<td>5-HT</td>
<td>++</td>
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*Ach*: acetylcholine (scopolamine, atropine)
*NE*: norepinephrine (MAO inhibitors)
*SHT*: serotonin (SSRIs, LSD)
“Poor” Sleep can Exacerbate, Trigger, or Even Cause Psychiatric Disorders
ADHD and Sleep Apnea

Huang et al. (2007) Sleep Medicine 8, 18-30.

6-Month Follow-up

Huang et al. (2007) Sleep Medicine 8, 18-30
Sleep is Critical for Emotional Balance

- Seung-Schik Yoo
- Ninad Gujar
- Matthew Walker

Emotional Memory After Sleep Deprivation

Yoo et al. (2007) Curr Biol 17, R877-878
Negative Stimuli

Yoo et al. (2007) Curr Biol 17, R877-878

Emotional Memory After Sleep Deprivation
Memory Recognition

Emotional Memory After Sleep Deprivation

Sleep Processes Different Kinds of Memory… in Different Ways
Sleep Consolidates Motor Learning

- Matthew Walker
- Tiffany Brakefield
- Alexandra Morgan

Sleep Enhances Performance
Sleep Consolidates Episodic Declarative Memory

Verbal Memory Task

Word Lists

Door  House  Ledge
Glass  Open  Breeze
Pane  Frame  Curtain
Shade  View  Window

D-R-M: 12-Hour Deterioration

% Change (relative to 20 min)

-60 -45 -30 -15 0 15

Studied words

Gist words

*
Sleep Enhances Insight

Number Reduction Task

- Ulrich Wagner
- Jan Born


Development of Insight
Sleep Enhances Infant Learning

Artificial Grammar Learning

Gomez et al. (2006) Psychological Science 17:670-674

Babies (15-mo) Learning the Rules
Sleep Enhances Adult Learning

“If you’re not dreaming about geometry...”

- Emily Hogeland
And school start times …

- At puberty, children undergo a biological “phase delay”.
- Their biological clock is altered so that both sleep onset and morning wake times are shifted to later times.
- Thus, getting an adolescent to go to bed at 10pm might be like trying to get you to bed at 8 or 9pm - It just doesn’t work!
It’s So Easy!

- Of all the interventions aimed at improving learning in children that we discuss, this may be both the easiest and cheapest.
- By educating parent, children, teachers and administrators, we may be able to improve children’s sleep, and I am confident that if we do, we will improve their learning.
- If we can get them to listen!

Part II: The Mind at Rest
Dream Content Predicts Spatial Memory Consolidation

**NREM Napping**

- Erin Wamsley
- Matt Tucker

NYTime.com April 22, 2010

Learning While You Dream

NYTimes.com April 22, 2010

Learning While You Dream

NYTimes.com April 22, 2010

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NYTimes.com April 22, 2010

Learning While You Dream
"I was thinking about the game that I used to play in high school, "Counter-Strike", because of the same layout . . . and also I was just planning, and trying to remember the maze and trying to figure out the route"

". . . thinking [about] what we have to do in the second maze test . . . wondered if it was going to be, like, the same . . ."

"I was thinking about the maze and kinda having people as check points, I guess, and then that led me to think about when I went on this trip few years ago and we went to see these bat caves, and they're kind of like, maze-like"

"Looking for something" in a maze

"Just hearing the music" from the task

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**Quiet wakefulness (useful?)**

**Dream reports (useless?)**

**Sleep-Dependent Memory Processing: Using the Whole Brain**

*Hippocampus*

- Stabilization and enhancement

*Neocortex*

- Salience selection
- Rule and gist extraction
- Network integration

*DREAMING*

- Narrative development (*navigation*)
- Future projection
- Theory of mind

*Who decides what we dream about?*
SNIP & FIT: A Model of the Resting Mind

SNIP & FIT

The Functional Incompleteness Theorem (FIT) – The brain has evolved to identify cognitive processes that fail to achieve their goals (i.e., to reach completeness)...

and then, attempts to complete them, through continued off-line processing – *Sustained Non-directed Incompleteness Processing* (SNIPping)
Nonconscious SNIPping

- “Senior moments” – memories recovered without awareness of continued search
- Insights - typically begin with a problem that has reached a dead end
- Sleeping on a problem – an answer without awareness of any decision-making process

SNIPping and the Default Network
(When nothing’s going on …)

- Episodic recall – What haven’t I finished?
- Theory of mind – What did he mean by that?
- Future projection – What am I going to do next?
  or at least for the “default” default network
Psychiatric Disorders of SNIPping

- Obsessive-compulsive disorder
- Autism spectrum disorder
- PTSD (pathological inability to complete)
- Anterior cingulate “error signaling” failures

FITful Sleep

- Sleep plays a special role in SNIPping
  - Sleep onset and 4AM awakenings
  - Sleep-dependent search for what’s important:
    - Emotional scenes
    - Gist extraction
    - Insight & rule extraction
FITful Dreams

• Dreaming play a special role in SNIPping
  ✓ Wish fulfillment (*Freud*)
  ✓ Threat avoidance (*Revonsuo*)
  ✓ Incomplete arrangements (*Hobson*)
  ✓ Maze-related dreams
  ✓ PTSD dreams (*not!*)

Summary

• Dreams appear to be a manifestation of sleep-dependent memory processing.

• But similar forms of off-line memory processing appear to occur during wake as well, in the form of “SNIPping”.

• Thus, sleep-dependent memory processing and dreaming may be continuations and refinements of this daytime processes, both in and out of “consciousness”.

• *And, arguably, much of what we “learn” we learn during this offline processing.*
Together, these systems carry out what may well be the most sophisticated function that the human brain performs – the building of a model of our world that provides clues to the course of our future and creates the meaning within our life.