Penn

Sleep and waking functions: What aspects of sleep should are important for healthy functioning?"

David F. Dinges, Ph.D.
Professor and Chief
Division of Sleep & Chronobiology
University of Pennsylvania School of Medicine
Philadelphia, Pennsylvania

FAA Workshop on Aircraft Noise Impacts Research
National Academy of Science Keck Center
Washington DC
10 December 2009

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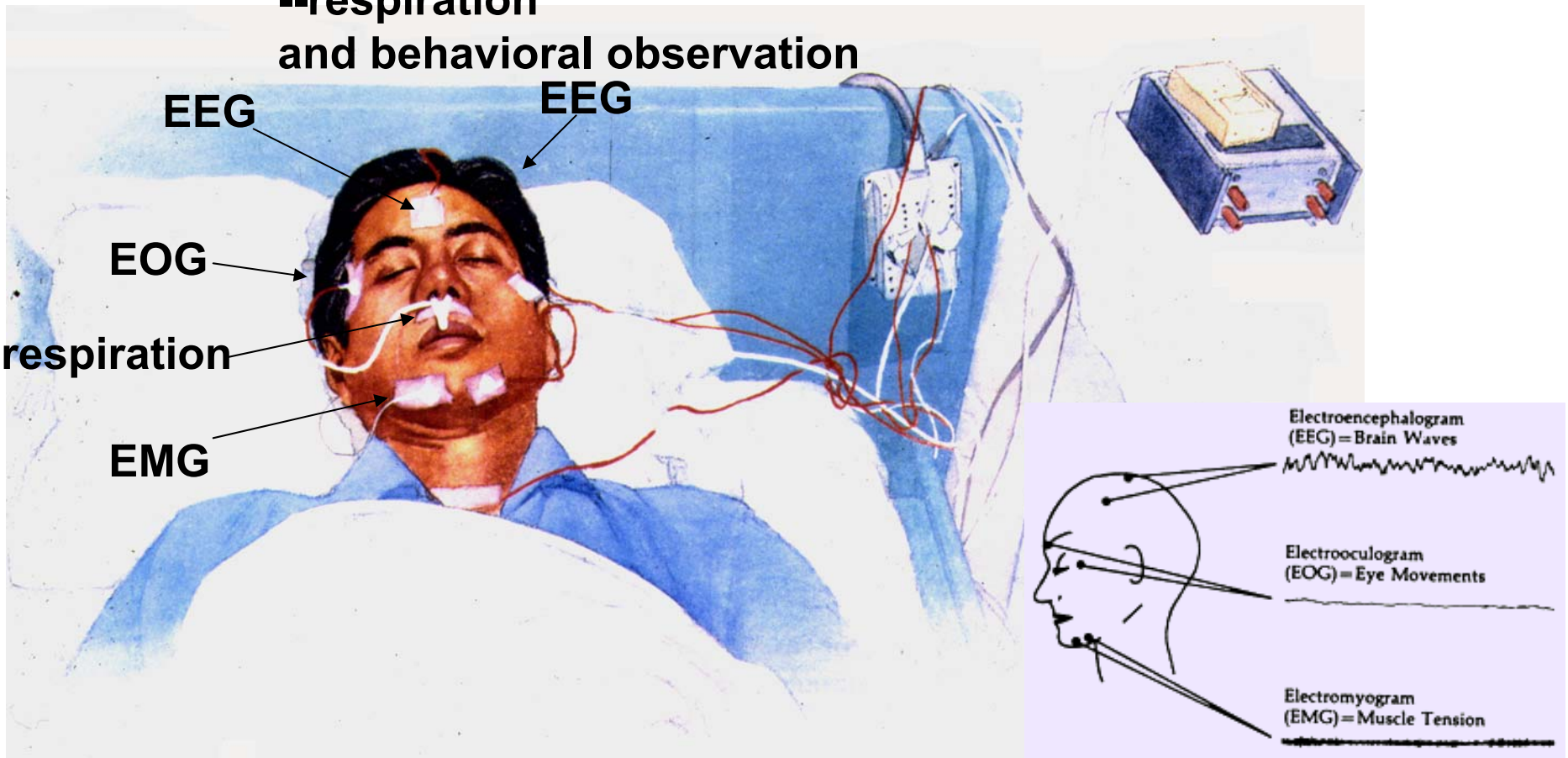
<u>Polysomnography</u> = surface electrophysiological recordings of…

--brain waves (electroencephalogram or EEG)
--eye movements (electrooculogam or EOG)
--muscle activity (electromyogram or EMG)
--heart rate (electrocardiogram or ECG)
--respiration
and behavioral observation



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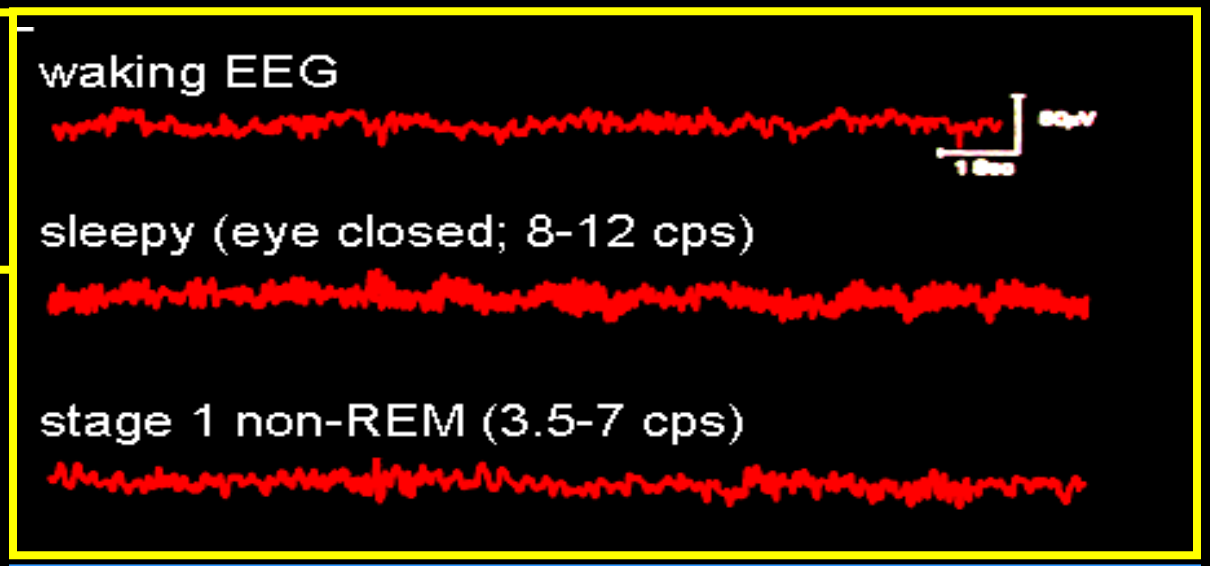
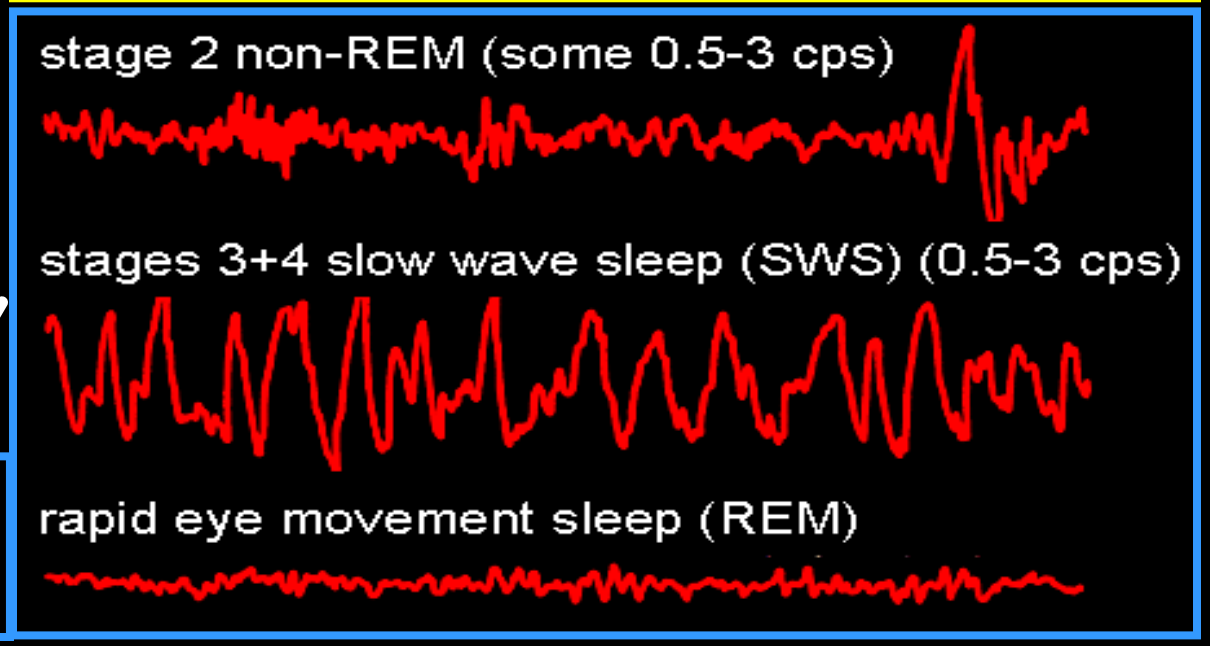
EEG from waking through the stages of sleep

Not restorative sleep



Increasing EEG hypersynchrony of non-REM sleep reflecting thalamo-cortical and reticulo-thalamo oscillations



Restorative sleep

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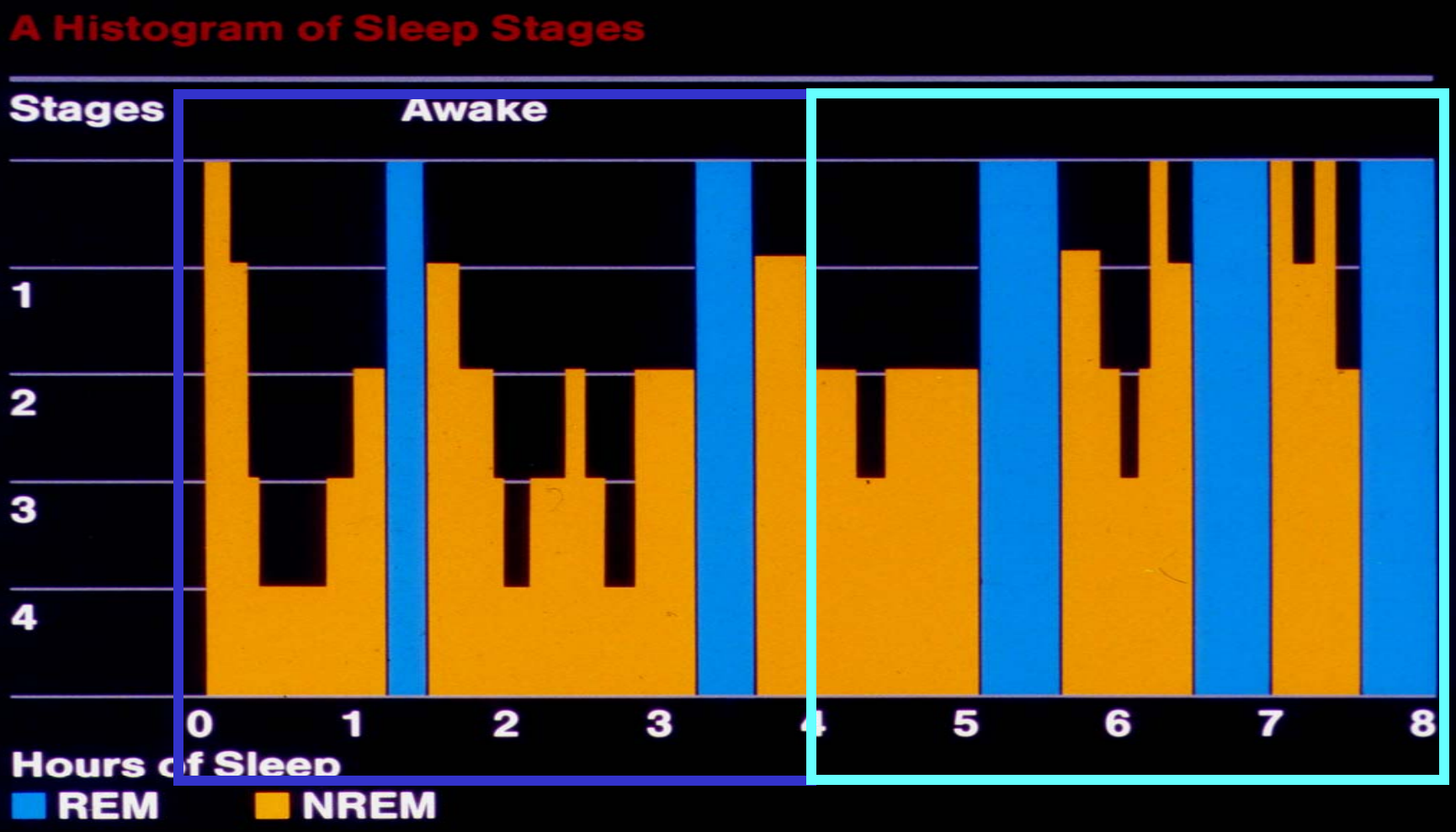
Ideal profile (hypnogram) showing the typical sequence of sleep stages across a night in a healthy young adult.



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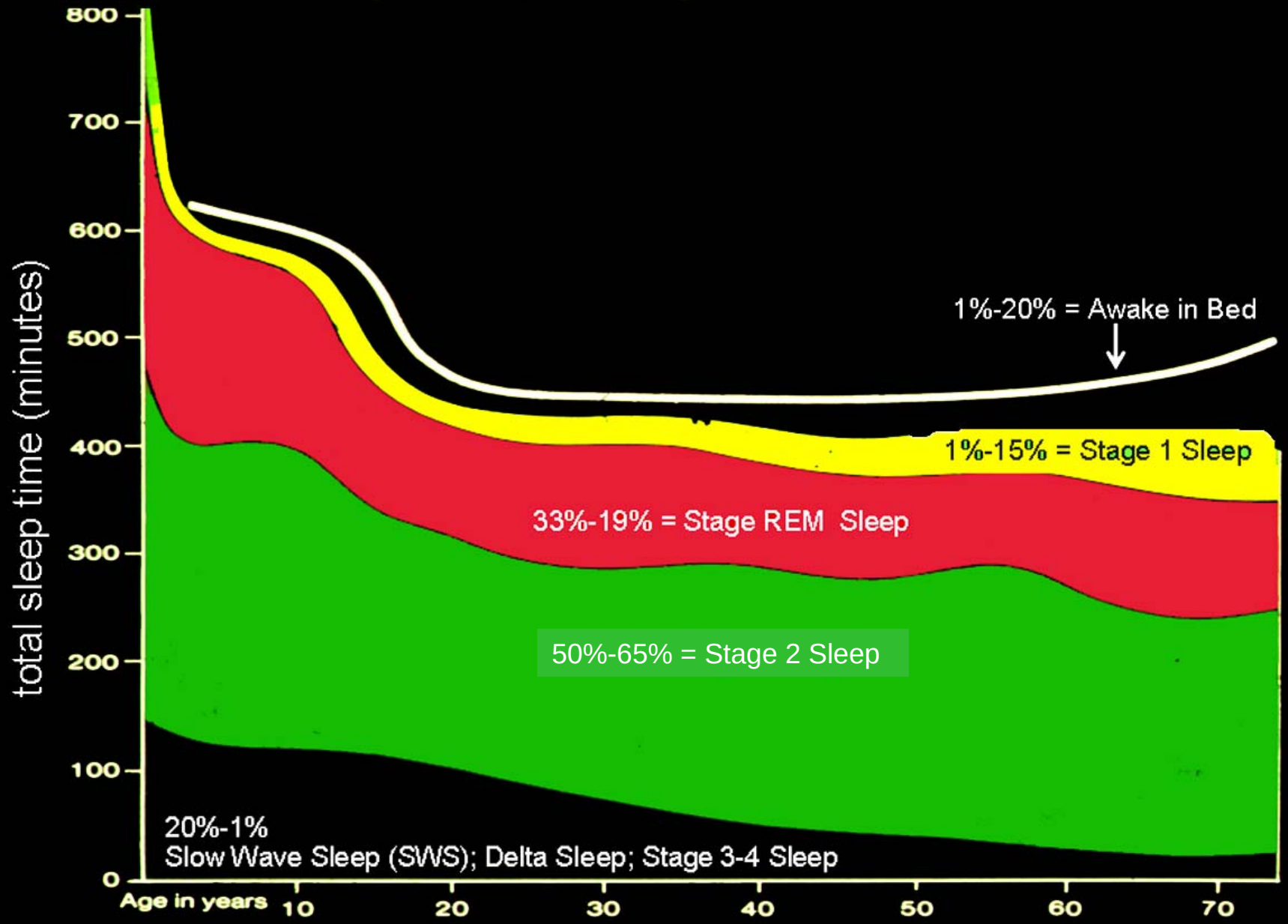
Development of Sleep over a Lifetime



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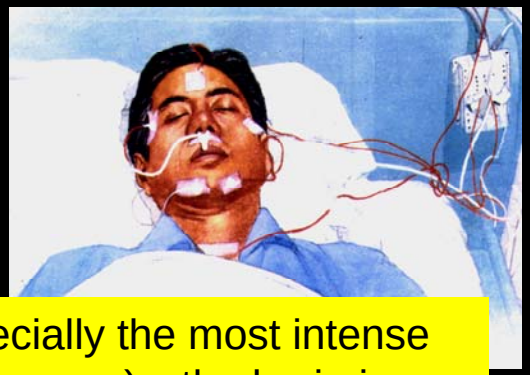
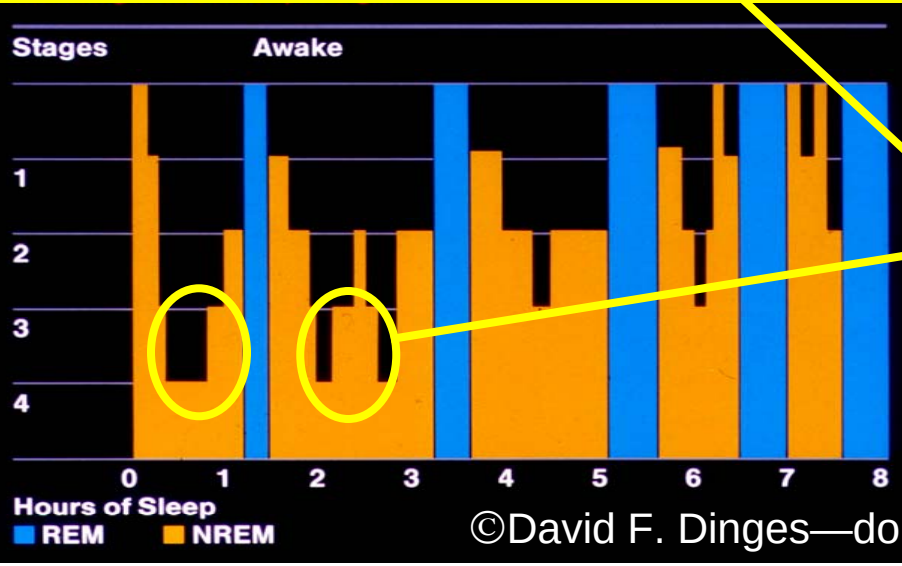
The continuity, intensity and duration of sleep contain the “recovery” that re-establishes stable waking cognitive functions: Sleepiness increases when as these aspects of sleep are diminished.



During sleep—especially the most intense sleep (EEG slow waves)—the brain is dynamically reorganizing. Forced awakenings at these times reveal an inability of the brain to use its waking cognitive functions such as working memory



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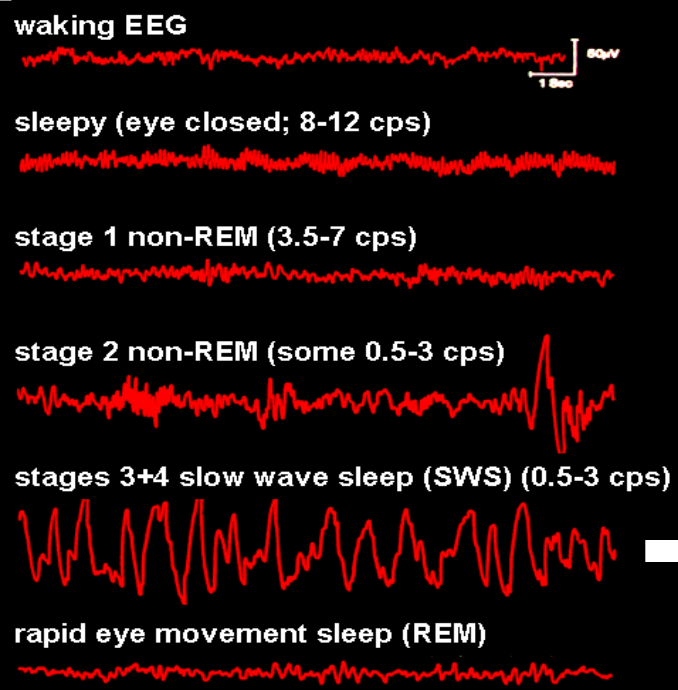
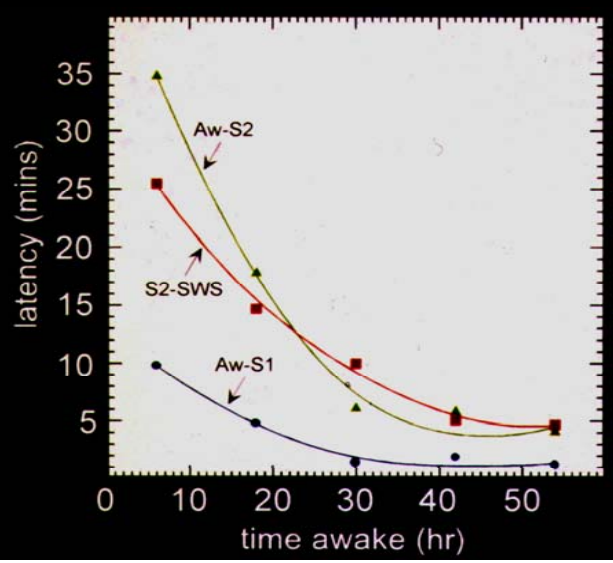
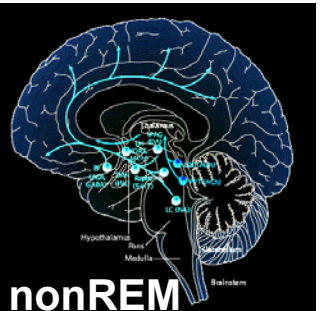
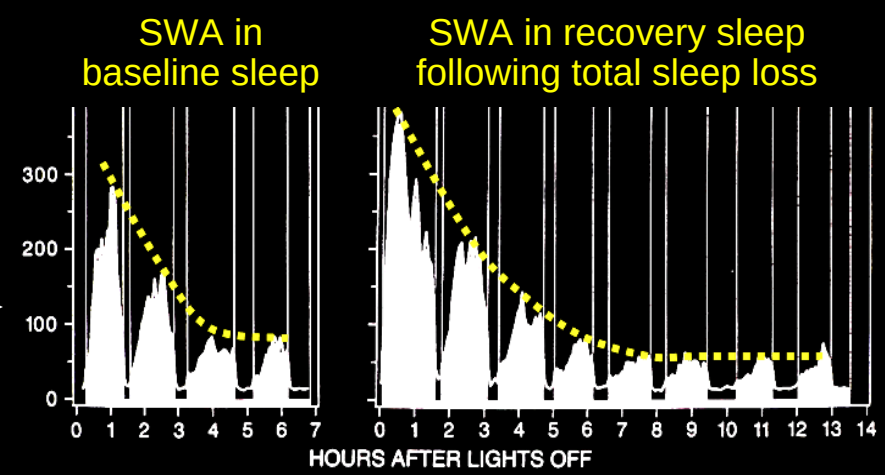
Elevated sleep drive results in faster transitions to sleep and to increased EEG slow waves

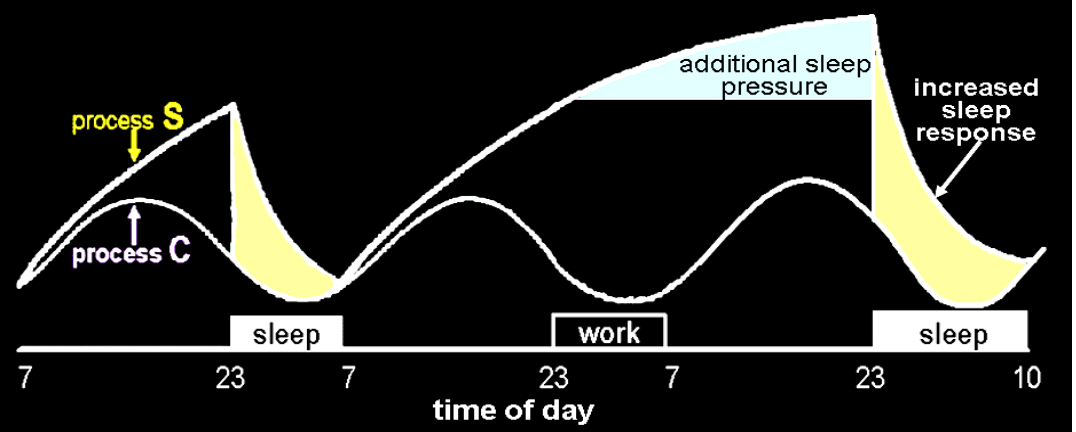






Two-process model posits nonREM EEG SWA (δ power) reflects homeostatic sleep drive





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Sleep loss can adversely affect a range of neurobehavioral functions depending on the amount of deprivation

Healthy sleep physiology and Adequate sleep duration

Effective behavior

- Mentally fast and accurate
- Stable attention and good focus
- Good memory (recall & working)
- Sound executive decision making
- New insights & creative solutions
- Less risky and risk taking
- Emotionally steady
- Feel good
- Realistic optimism

Disturbed sleep physiology and / or Inadequate sleep duration

Ineffective behavior

- Mentally slow and inaccurate
- Variable attention and poor focus
- Unreliable memory
- Weak executive decision making
- Fewer insights/creative solutions
- More risky and risk taking
- Emotionally flat / unpredictable
- Feel tired / stressed / exhausted
- Unrealistic and pessimistic

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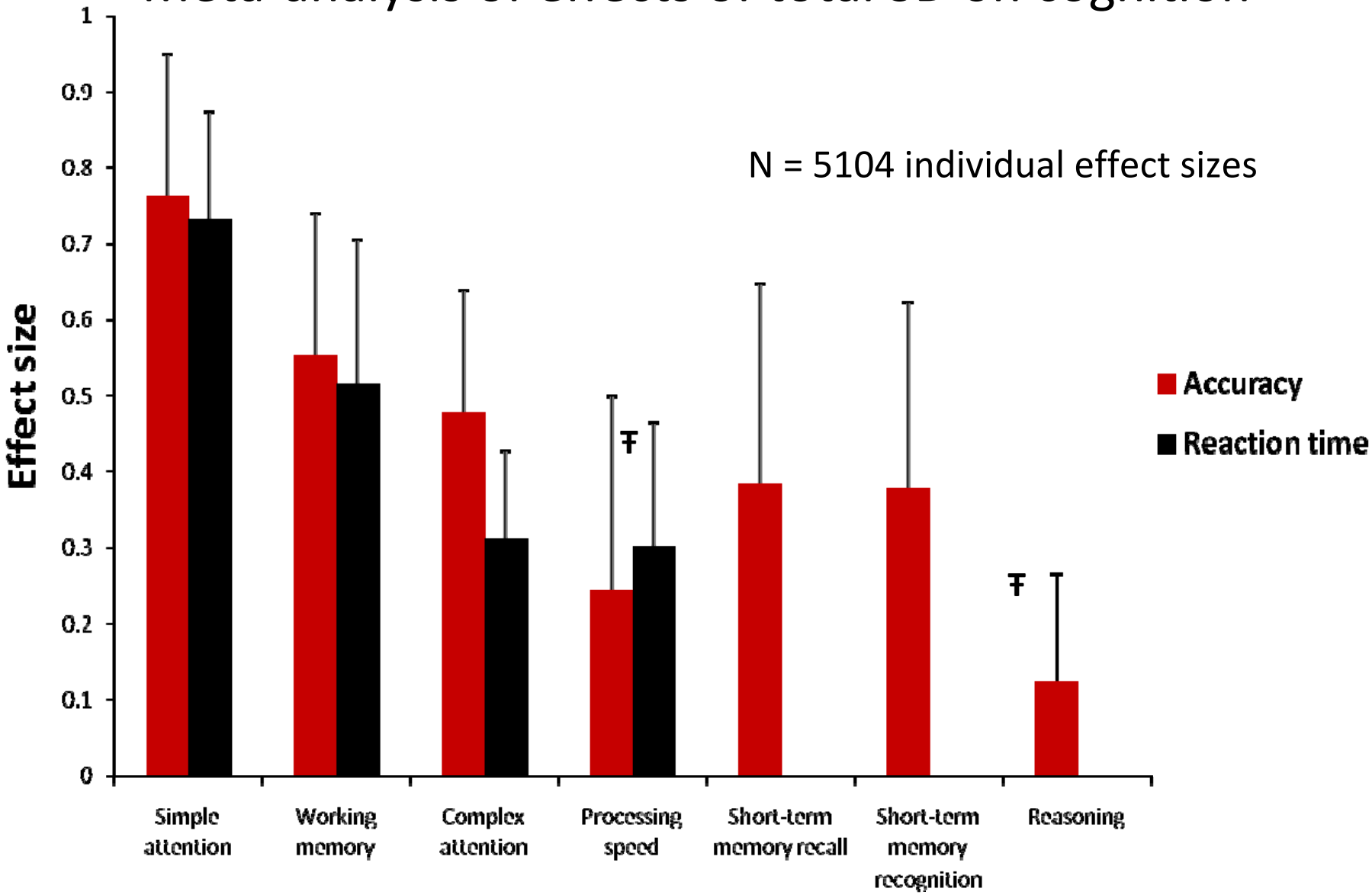
Meta-analysis of effects of total SD on cognition



Lim and Dinges *Psychological Bulletin* (in press)

Bars represent 95% confidence intervals

Ŧ: *not* significant at $p < .05$

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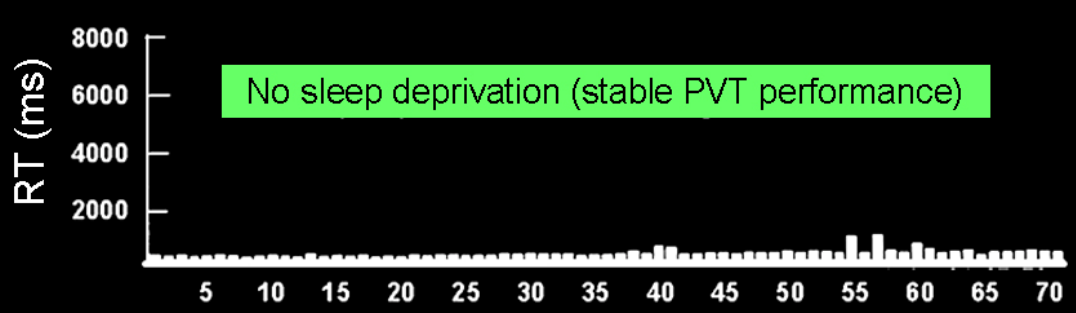
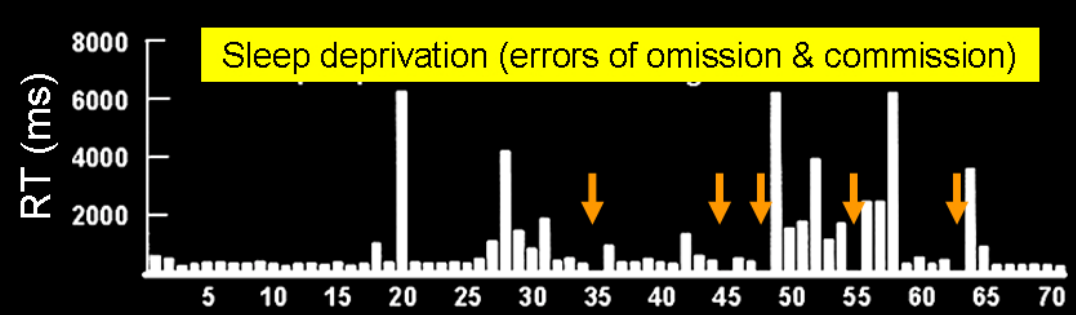
Psychomotor Vigilance Test (PVT) meets all of the criteria for an assay sensitive to differential vulnerability to SD

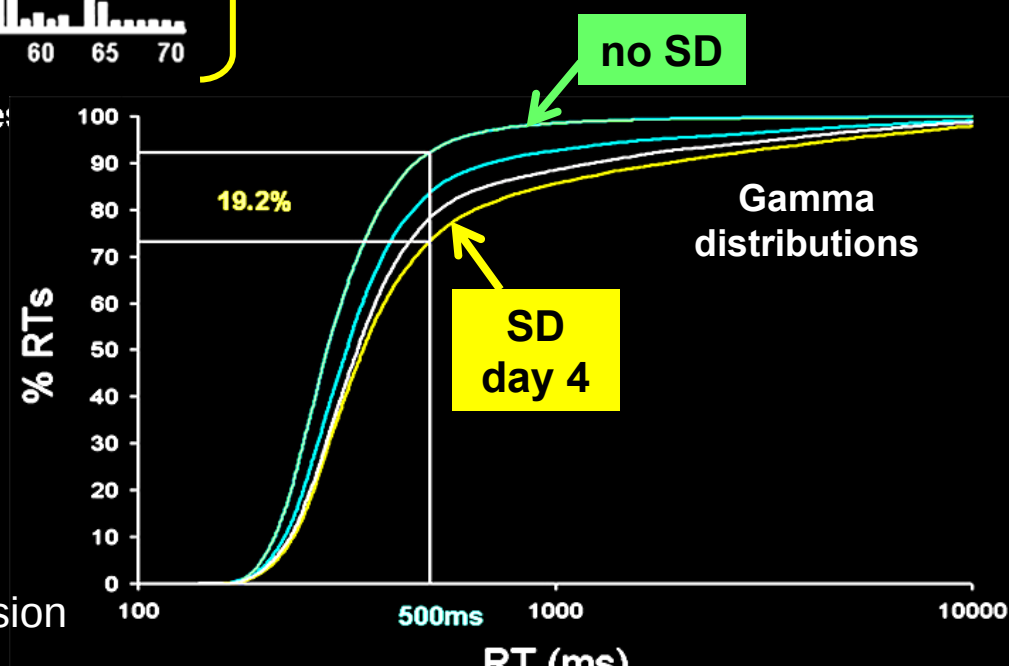


stable wakefulness



state instability

Consecutive PVT reaction times



Dinges & Powell (1985)
Dinges DF & Kribbs (1991)
Doran SM, Van Dongen HPA, Dinges DF (2001)
Lim J & Dinges DF (2008)

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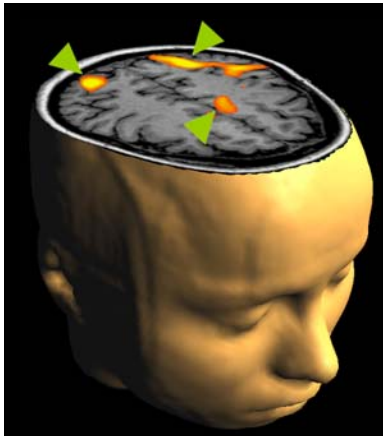
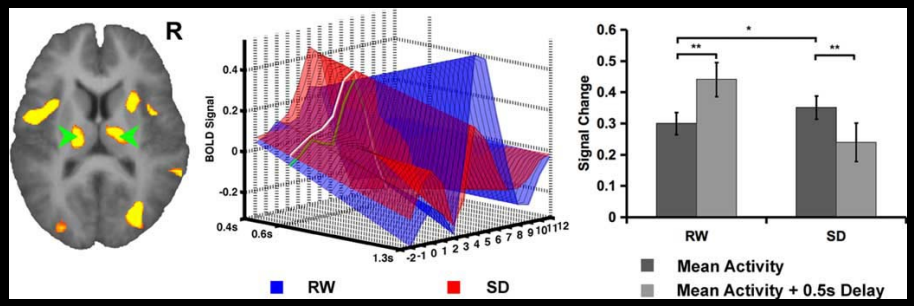
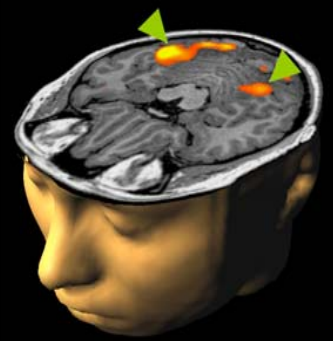


New neuroimaging evidence shows lapses involved distributed brain regions





fMRI during a visual, selective attention task

- Sleep-deprivation lapses differed from lapses after normal sleep.
  - reduced ability of frontal and parietal control regions to raise activation to lapses
  - reduced visual sensory cortex activation
  - reduced thalamic activation
- Fastest responses after normal sleep and after sleep deprivation elicited comparable fronto-parietal activation.
- Performance while sleep deprived involves periods of normal neural activation interleaved with periods of depressed cognitive control (PFC), visual perception (VC), and arousal (Thalamus).

Chee MLW et al.: *Journal of Neuroscience*, 28(21):5519-5528, 2008.

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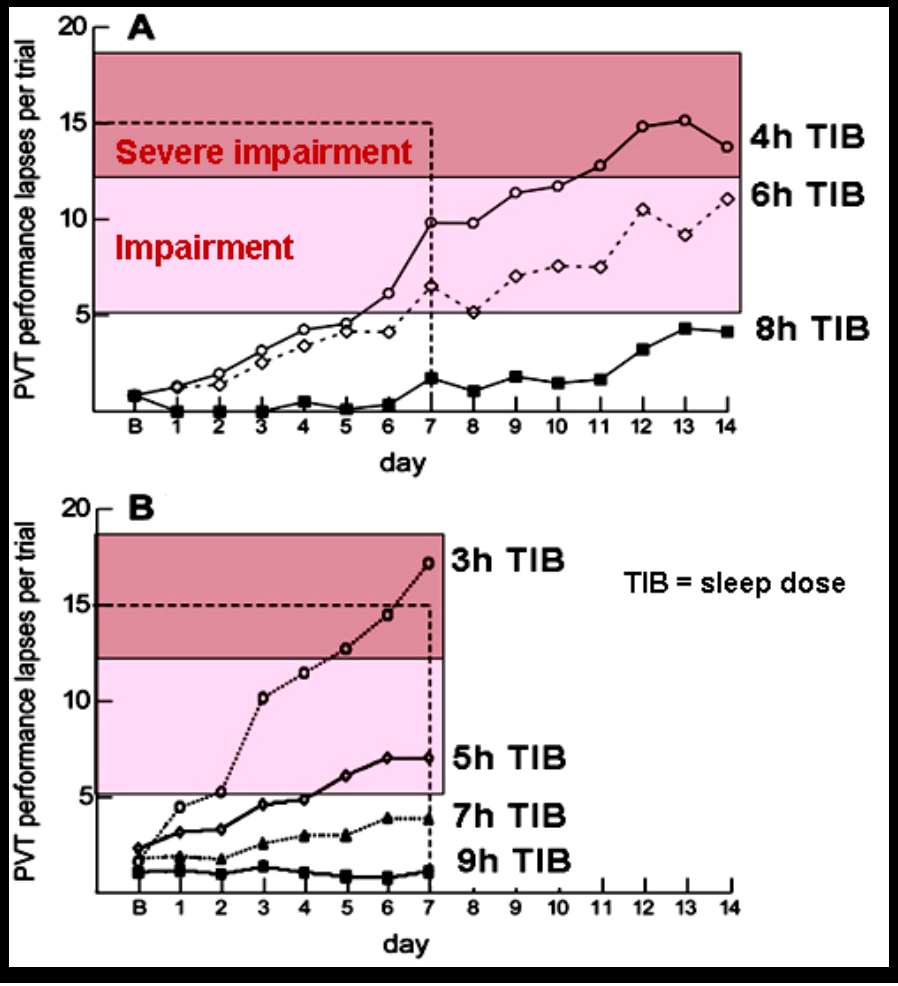
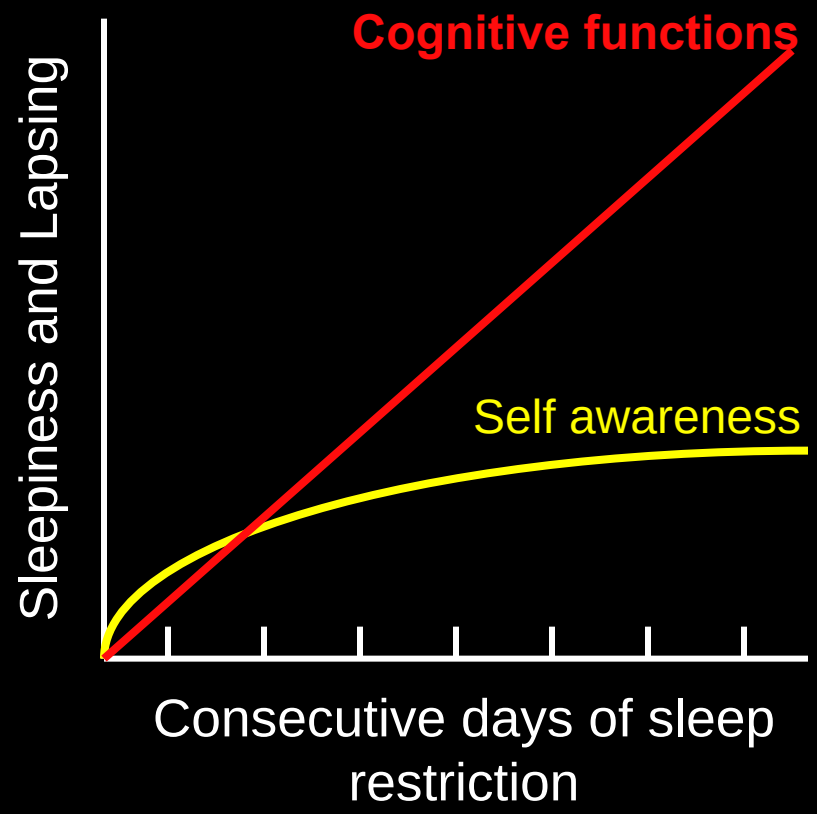
Sleep loss is cumulative and people may not be fully aware of the extent to which it is affecting their functioning

In healthy adults (22-55 years) behavioral lapses occur more frequently with each day of sleep duration below 7 hours





Van Dongen et al., SLEEP (2003)
Belenky et al. J Sleep Research (2003)

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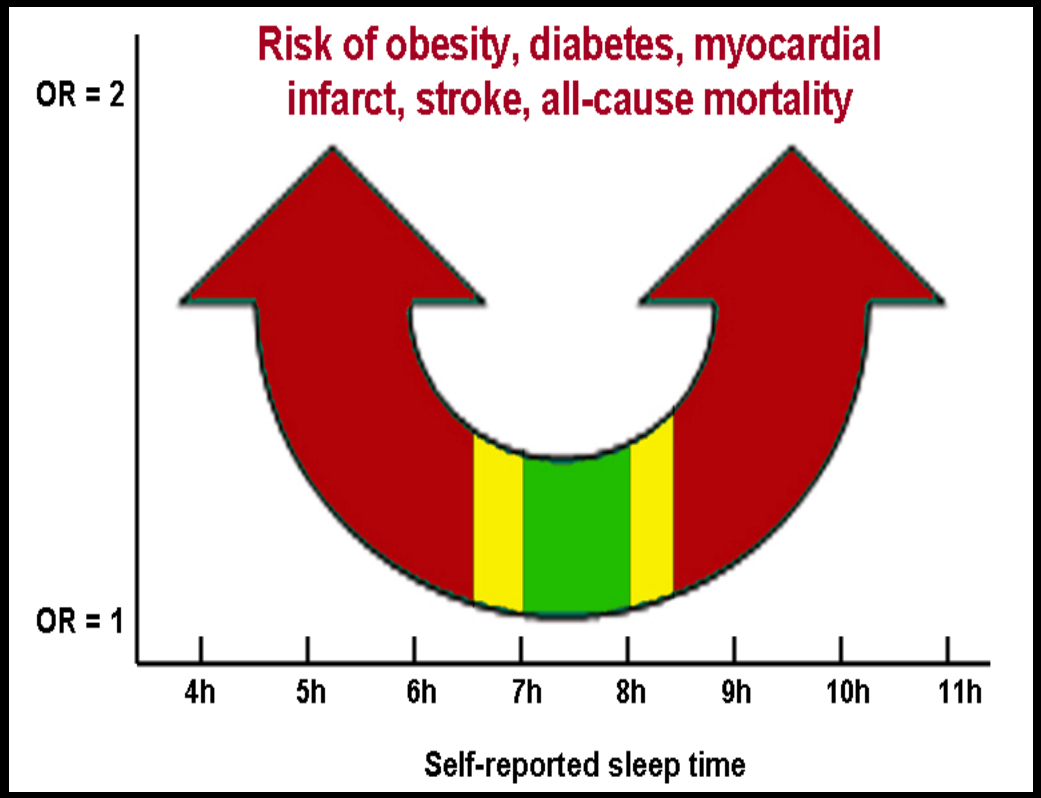
Sleep loss has become important for **Public Health**

Population studies from all over the world suggest sleep duration has a u-shaped relationship to prevalent health risks



Should increased sleep duration be a public health intervention like diet and exercise?

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EXAMPLES

OBESITY

45 studies (N = 634,511) from around the world found short sleep associated with obesity.

Children: Pooled OR = 1.89
Adults: Pooled OR = 1.55
Cappuccio et al. (2008)

CANCER

WHO – studies show night shift work is carcinogenic.

MORTALITY (all causes)

22 studies from around the world found both short and long sleep duration associated with mortality (from alll causes).

Simpson et al. (2009)

Self reports about sleep and sleepiness have limited validity

- People remember only a subset of awakenings and few specific arousals (e.g., due to sleep inertia)

- Sleep complaints can be uncorrelated with sleep architecture (e.g., some insomniacs have relatively normal PSG)

- People can have high rates of arousal with no awareness (e.g., untreated apnea may result is 30-60 arousals/hr without awareness)

- Global estimates of sleep time are overestimates of sleep relative to wrist actigraphy, which overestimates sleep relative to polysomnography (PSG)

- Psychometric scales of sleepiness are relative and can underestimate sleepiness for reasons that are as much biological as psychometric

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Vulnerability to noise disturbances of sleep may or may not be greater in certain subgroups

- Adults with high vulnerability to arousal/awakening
- Adults with high vulnerability to the effects of sleep loss
- Children and adolescents
- Elderly (↓sleep drive, ↑awakenings from nocturia, pain, etc.)
- People with insomnias
- People with shift work sleep disorder and jet lag disorder
- People with sleep apnea syndromes
- People with insufficient sleep syndrome
- People with neuropathologies (PLMS) &/or hypersomnolence

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Drugs/medications can affect sleep physiology; arousals during sleep; recall of arousal during sleep; and daytime sleepiness

- Hypnotics (sleeping pills)
- Sedative medications
- Muscle relaxants
- Anxiolytics
- Opioids
- Alcohol
- Stimulants (caffeine, tobacco, etc.)

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