

Working Time and Fatigue Management

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NASA AMES FATIGUE
COUNTERMEASURES LAB

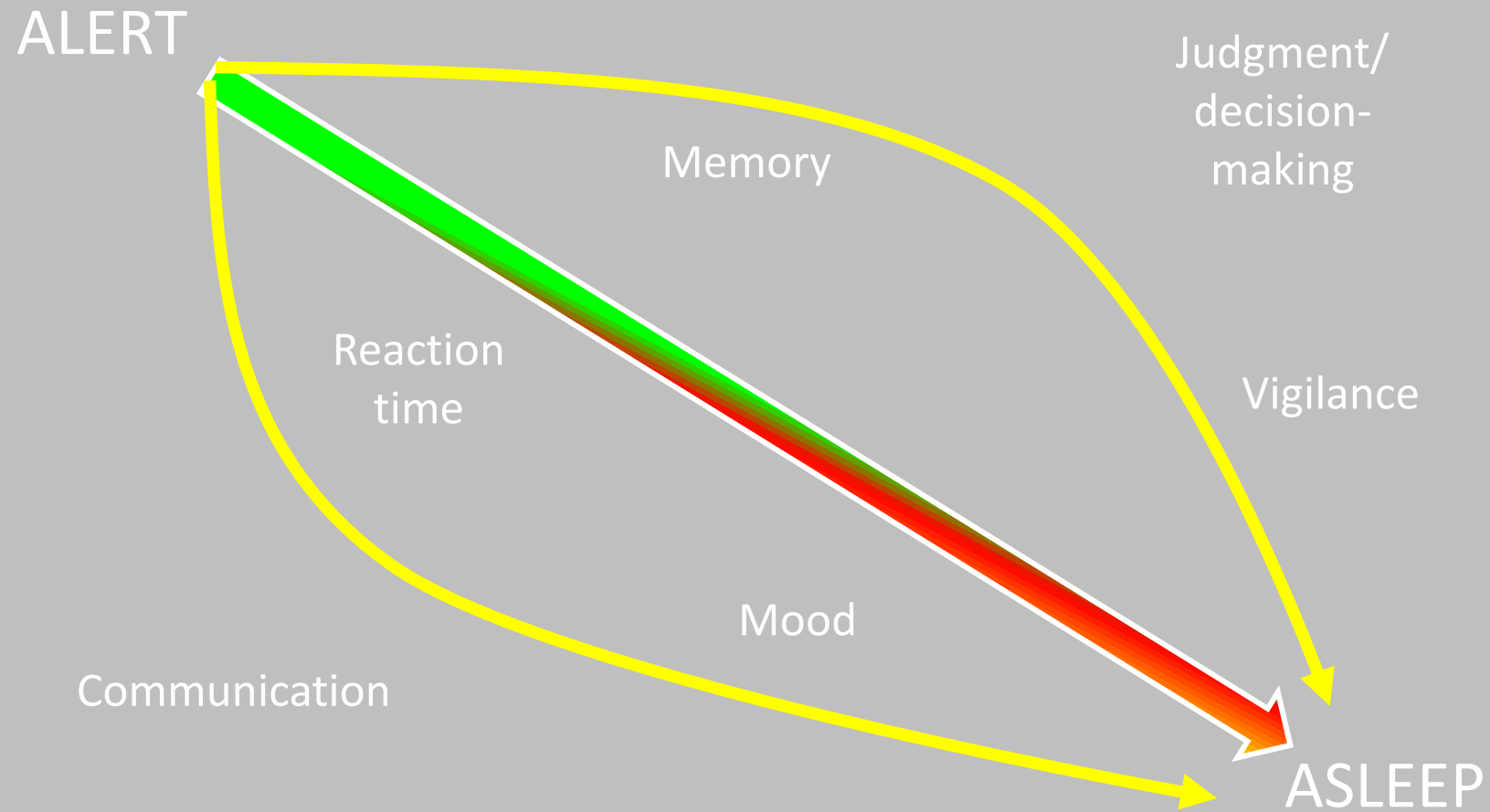
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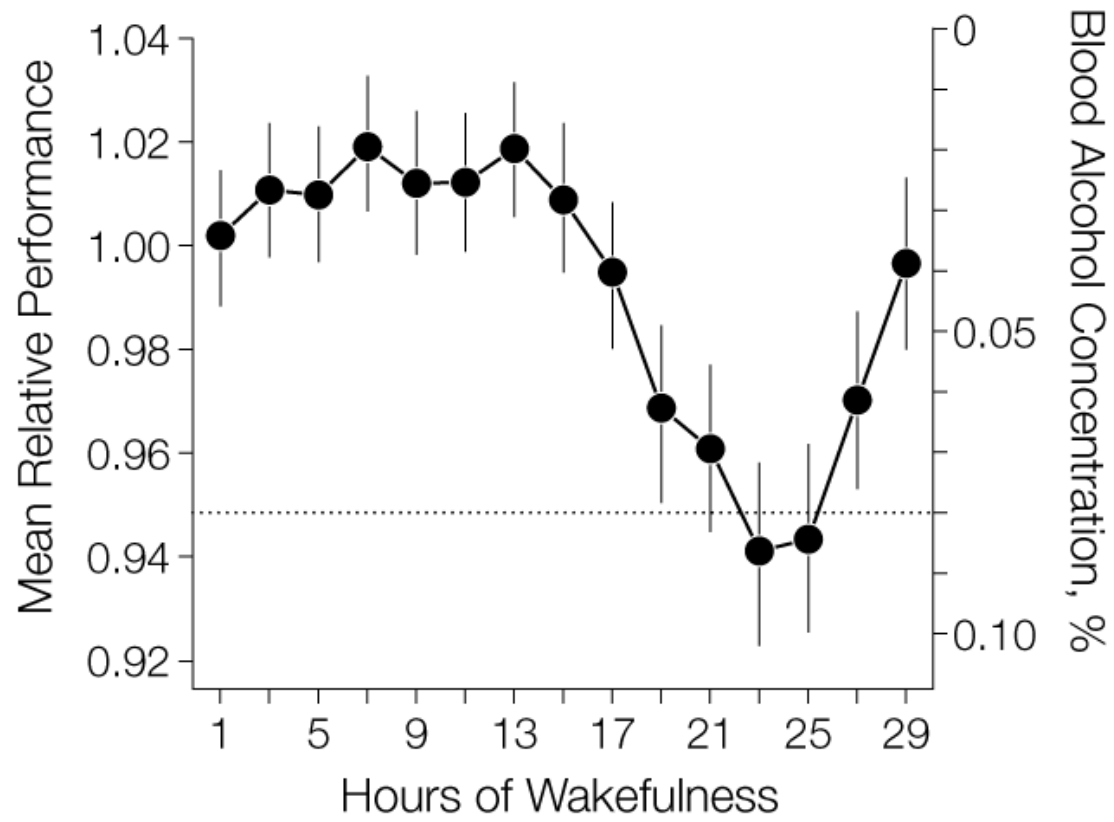
Fatigue Defined

- “An unsafe condition that can occur relative to the timing and duration of work and sleep opportunities” (Institute of Medicine)
- “The potentially detrimental impacts of unusual shifts and prolonged work-times shall be...a high priority by all NASA centers...safe work practices that minimize human error factors, especially fatigue...” (NASA NPR 1800.1D)

Fatigue: A Performance Issue



Fatigue: A Performance Issue



Lamond, Dawson; J Sleep Res, 1999



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Causes of Fatigue

Acute sleep loss
(e.g., staying awake too long)

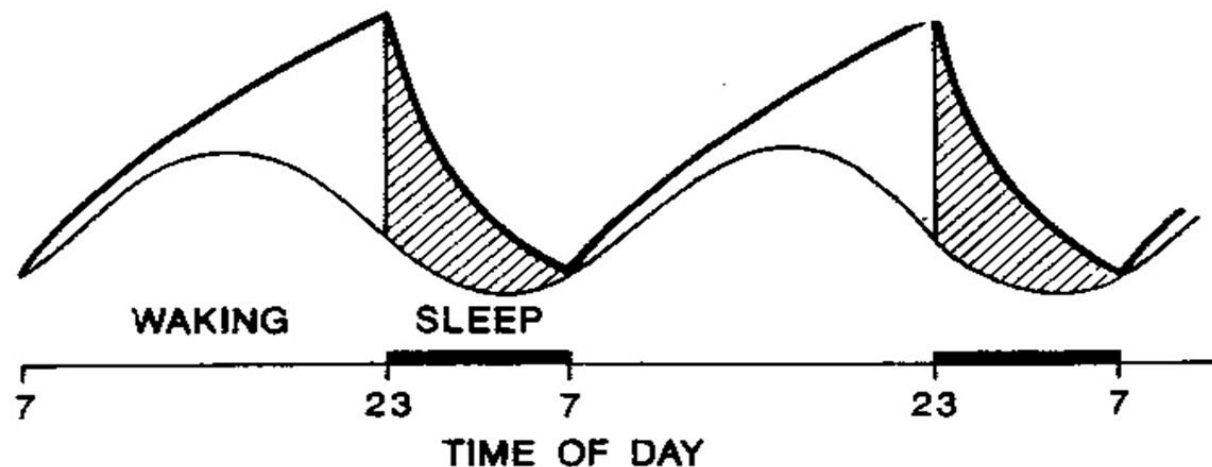
Cumulative sleep loss
(e.g., losing a little sleep
several nights in a row)

Circadian misalignment
(e.g., trying to stay awake at
night when your body is
designed to sleep)

Poor sleep quality
(e.g., disrupted by noise, sleep
disorders)

Sleep and Circadian Rhythms

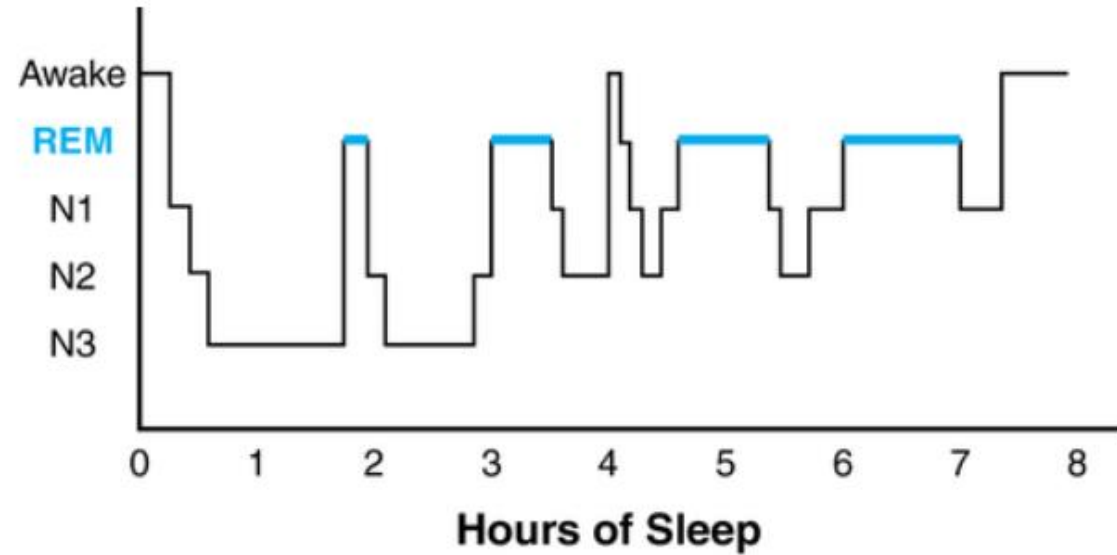
- Two process model
 - Process S: pressure for sleep increases with more hours awake
 - Process C: follows a daily rhythm



Borbely & Achermann, 2000

What is Sleep?

- Two kinds of sleep
 - Non-REM
 - Light and deep stages of sleep
 - Mental and physiological activity slow down
 - REM (rapid eye movement)
 - Active brain (dreaming) in paralyzed body



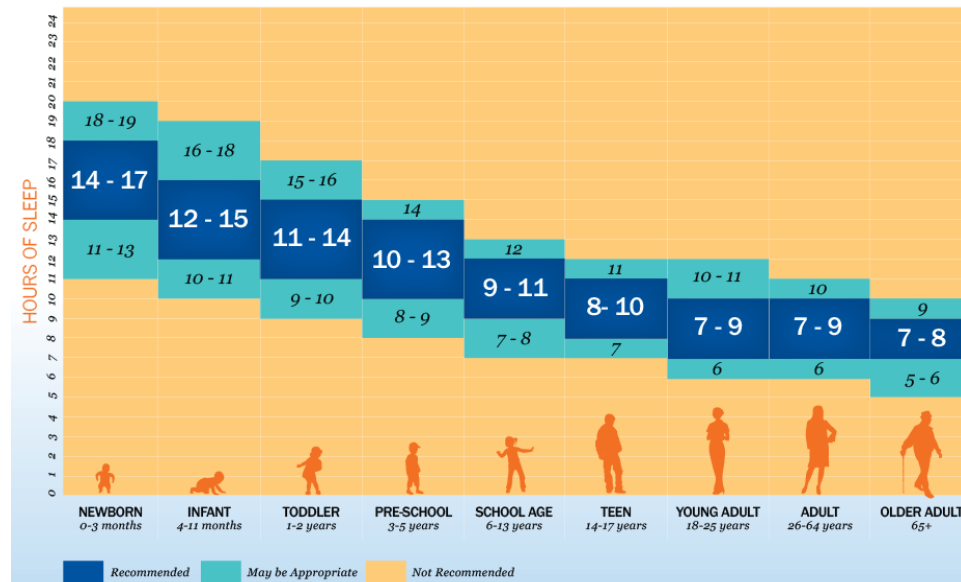
Normal adult hypnogram: Slow wave sleep (N3) is more prominent during the first portion of the night. REM episodes increase as the night progresses with the longest episode before awakening.

Neubauer, 1999

Sleep Need?

 NATIONAL SLEEP FOUNDATION

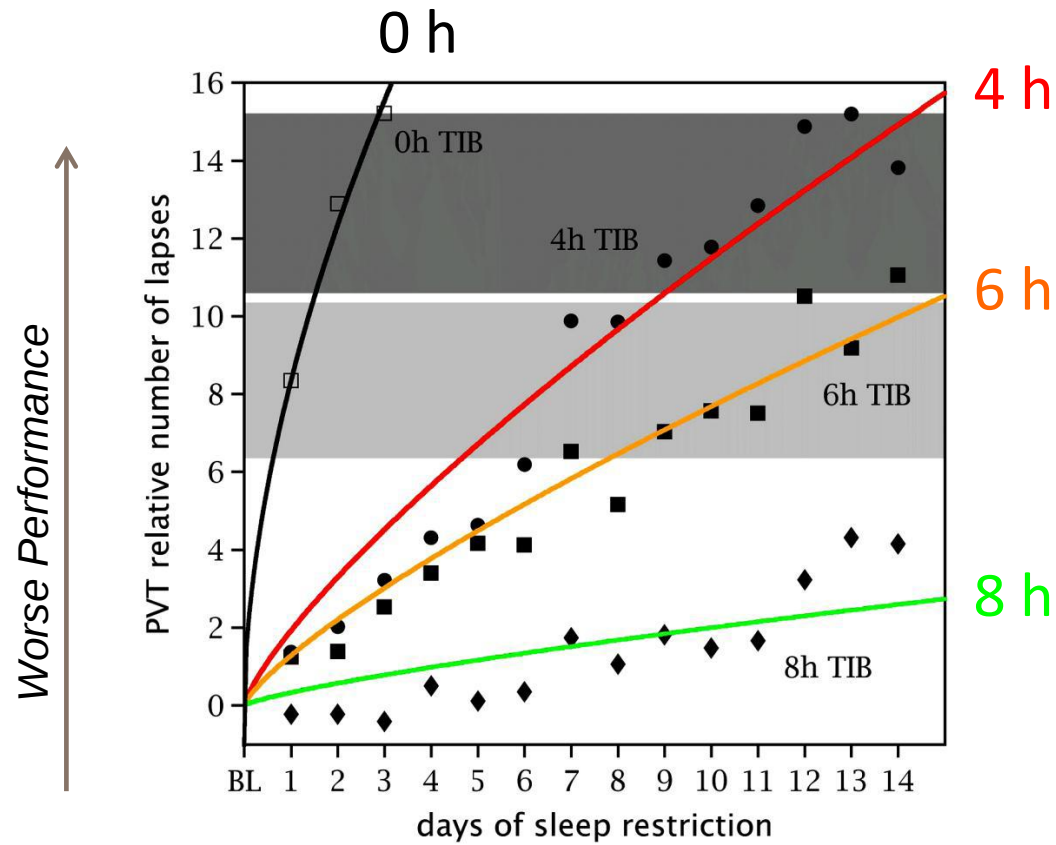
SLEEP DURATION RECOMMENDATIONS



SLEEPFOUNDATION.ORG | SLEEP.ORG

Hirshkowitz M, The National Sleep Foundation's sleep time duration recommendations: methodology and results summary, Sleep Health (2015), <http://dx.doi.org/10.1016/j.sleh.2014.12.010>

Chronic Sleep Loss



Van Dongen et al., 2003

Recovery from Sleep Loss

- Increased duration
- More deep sleep
- For short term sleep loss
 - two nighttime sleep periods
- For longer term sleep debt
 - May require several night sleeps to return to normal functioning levels
 - Circadian misalignment a factor

Sleep Inertia

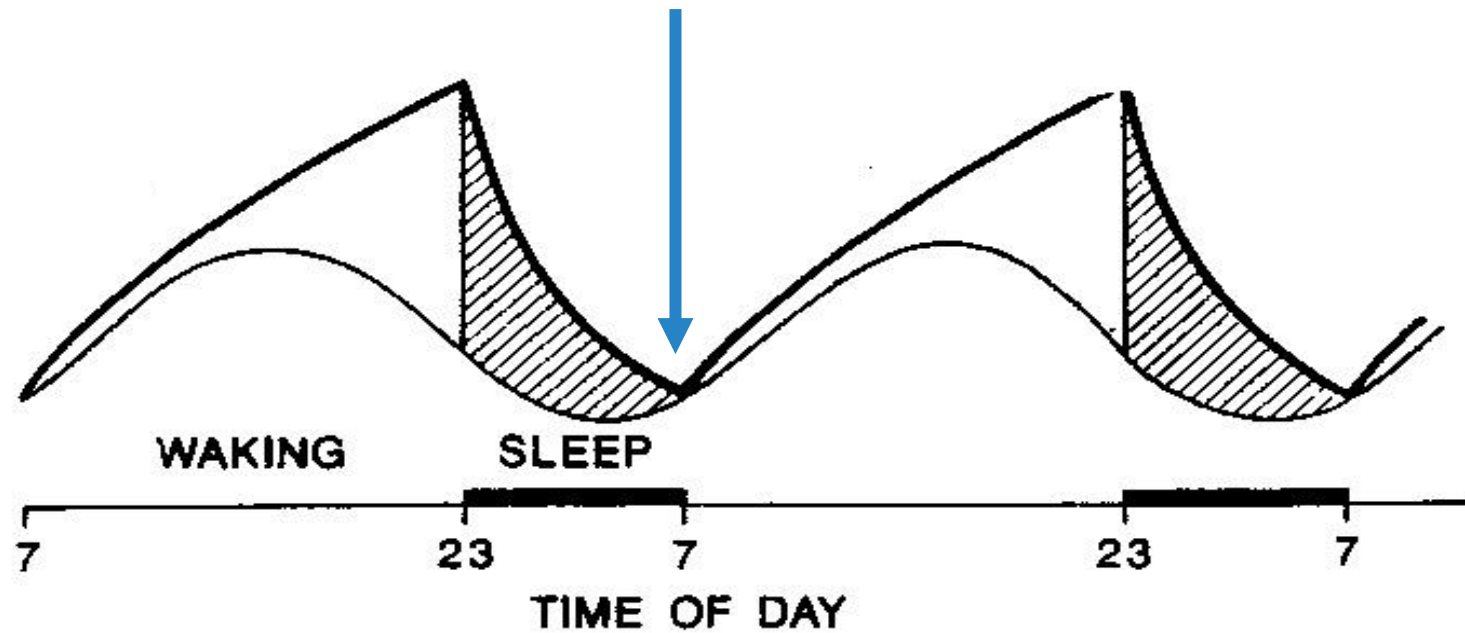
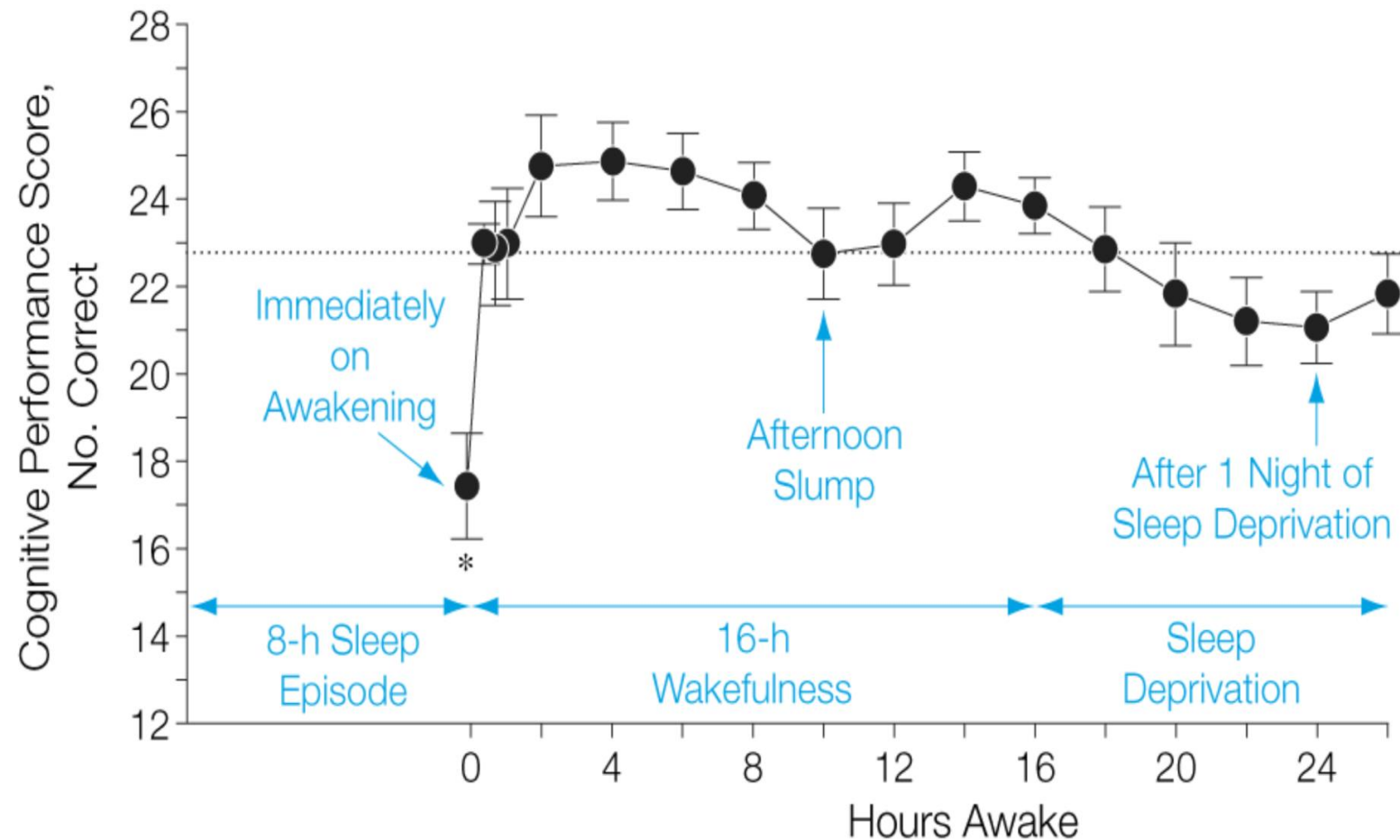


Photo by Maks Styazhkin on Unsplash

Sleep Inertia



Wertz et al., 2006

Circadian Rhythms

- *Circa* = about; *dies* = day
 - All living creatures show circadian rhythms
 - Normal environmental stimuli (light/dark cycle) can entrain rhythm to 24 hrs
 - There are many different systems that follow this rhythm
 - sleep/wake
 - body temperature
 - mental performance
 - hormones
 - digestion
- Image from <https://upload.wikimedia.org/wikipedia/commons/0/0d/Clock.jpg>

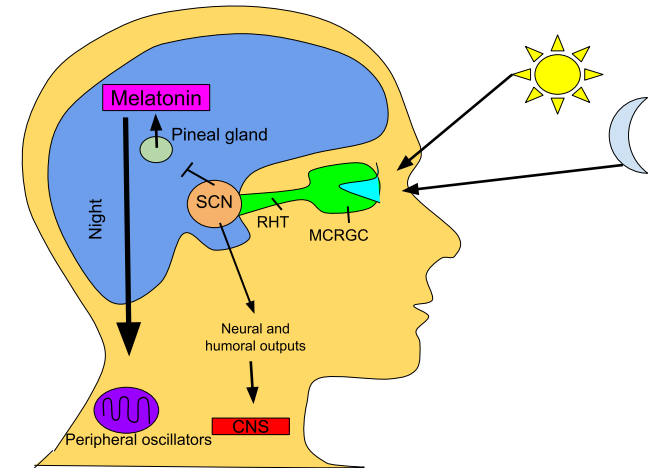


Image from https://upload.wikimedia.org/wikipedia/commons/e/e6/Circadian_rhythm.svg

Circadian Rhythms: the Daily Clock

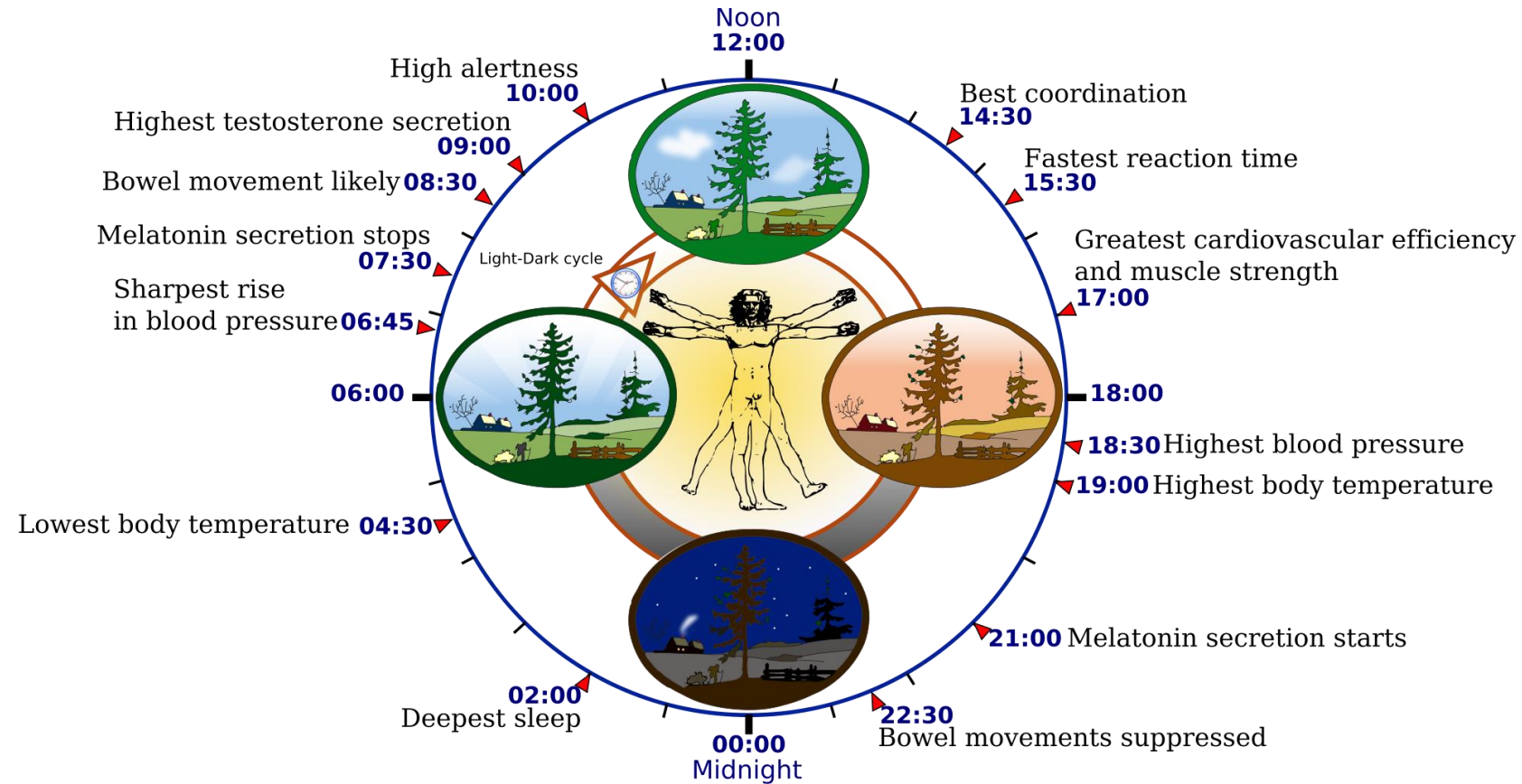
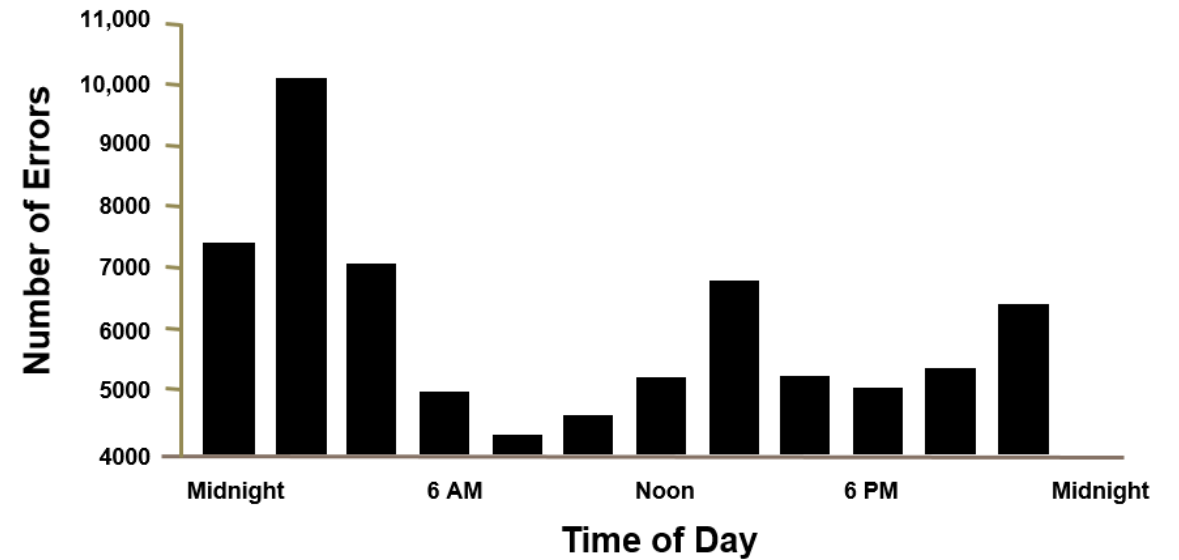
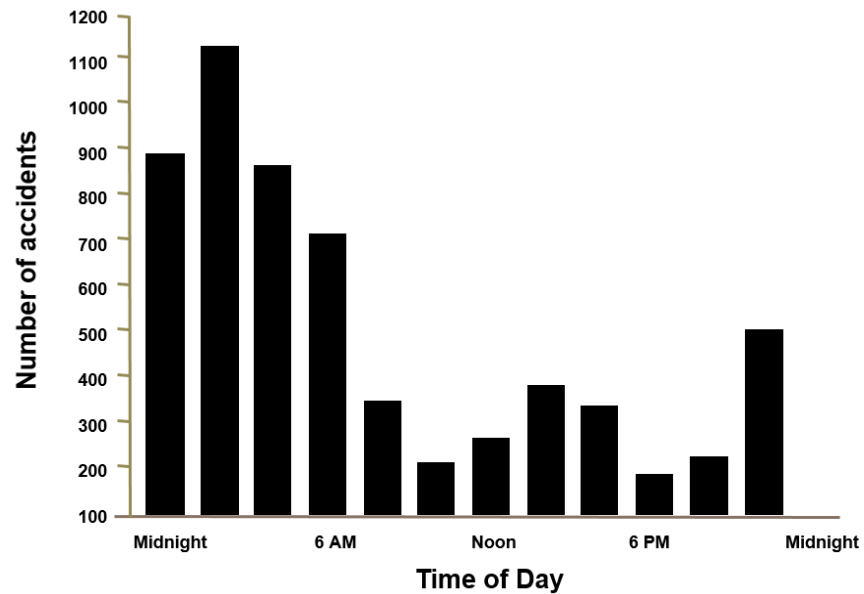


Image from https://upload.wikimedia.org/wikipedia/commons/3/30/Biological_clock_human.svg

Circadian Rhythms and Safety

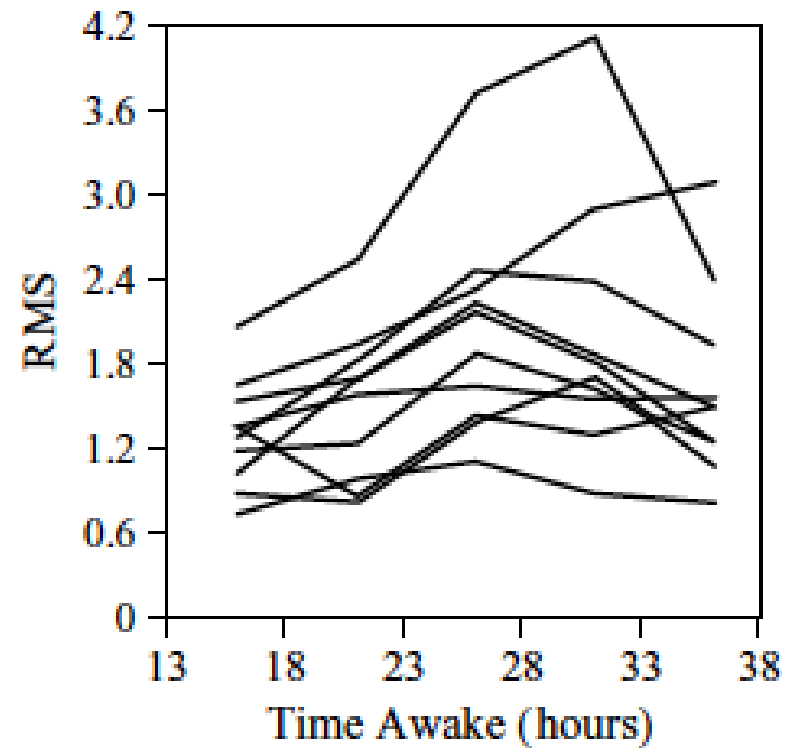
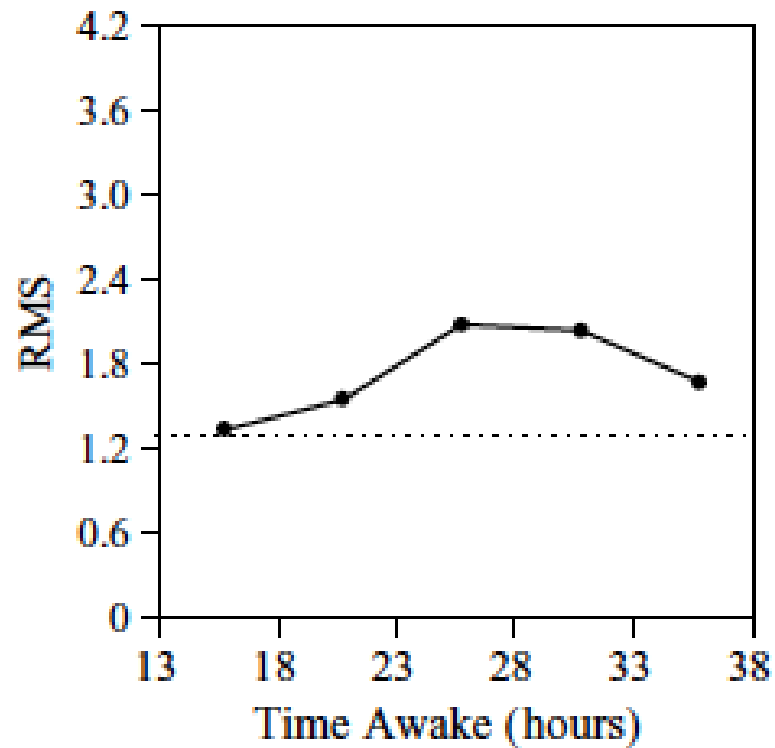


Mitler et al., Sleep, 1988

Circadian Misalignment

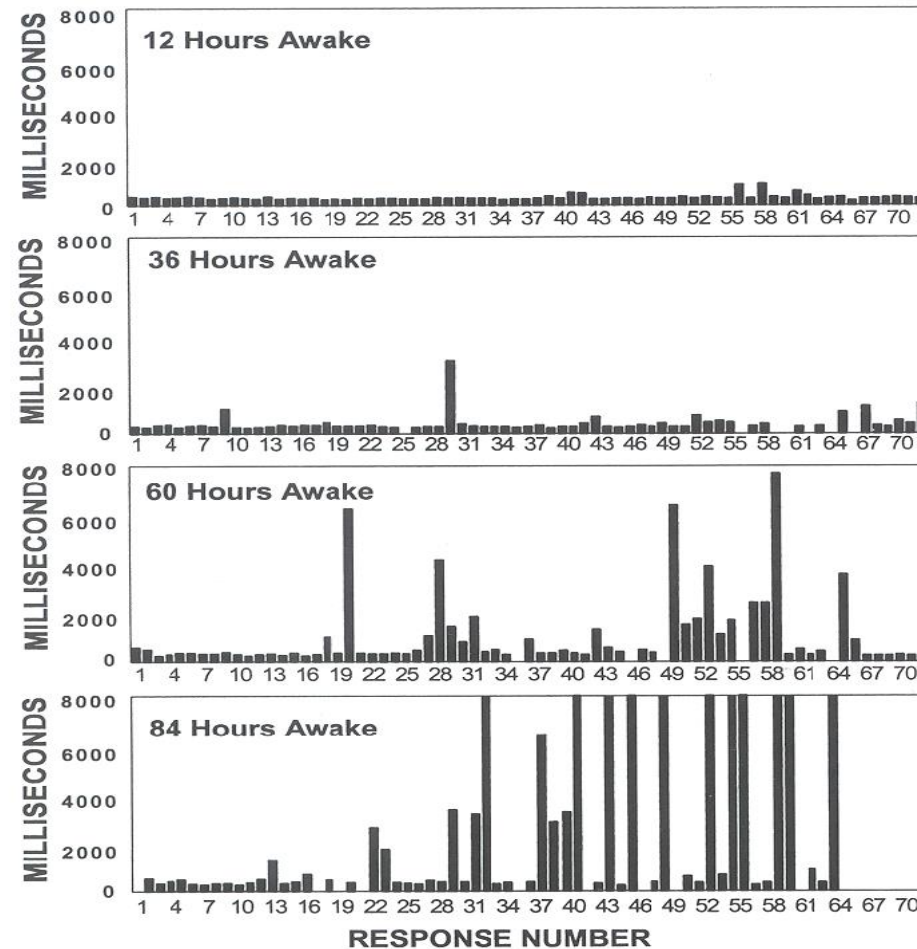
- Misalignment between sleep/wake cycle and timing of clock
- Circadian clock can not adapt immediately to work/rest schedule changes
- Some individual variation in programming of the clock (chronotype)
 - Morning types= “larks”
 - Evening types= “owls”
 - Clock cycle for “owl” up to 5 hr later than “lark”

Individual Differences



Van Dongen et al., Sleep, 2006

State Instability



Doran et al., 2001

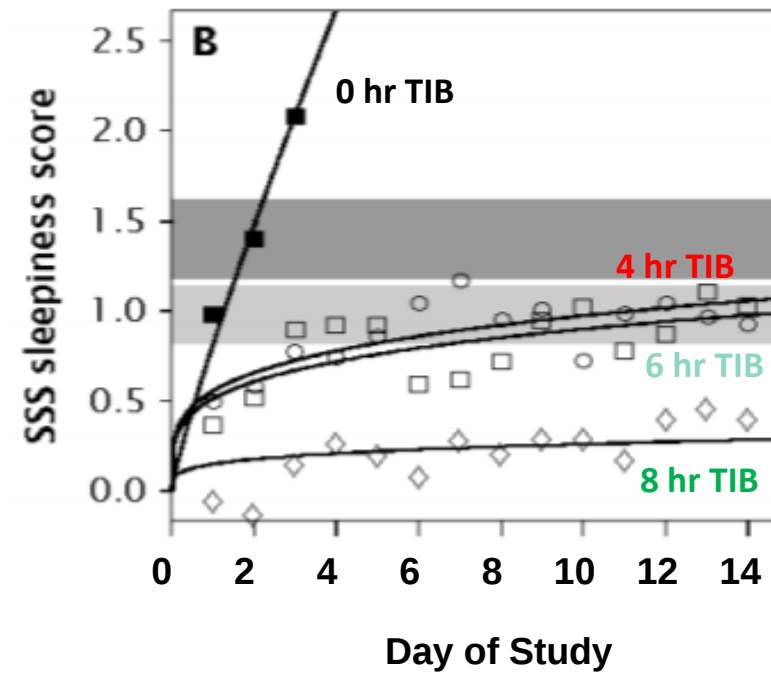
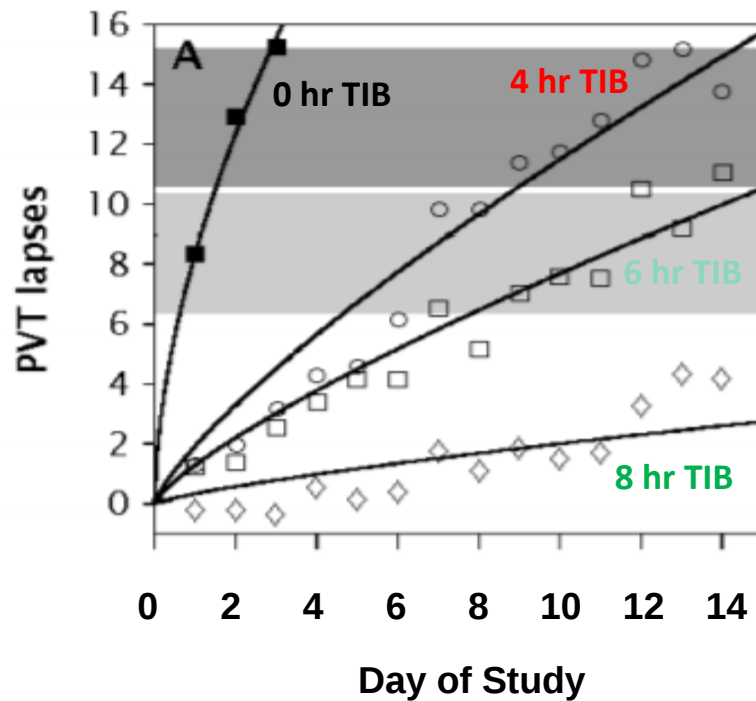
Common Misperceptions

I know how tired I am.

*I have lost sleep
before and did just
fine.*

*Motivation and stimulation
will get me through.*

Self-Assessment



Van Dongen *et al.* 2003

Fatigue Management: NASA NPR 1800.1D

Employees in critical positions limited to:

- 12 hours (16 in emergency* situations with approval**)
- 60 hours/week
- 7 consecutive days
 - 18 days with pre-approval, then need 2 days off**
- 240 hours/4-week period
- 2500 hours/rolling 12-month period

* “Emergency or extremely unusual circumstances can require work performance essentially at endurance capacity...invoked only for life-threatening emergencies, natural disasters, mass casualty accidents, or war” (1800.1D.2.14.3.6)

** “pre-approval is required for deviations by a supervisor after consideration of human factors safety issues for the Critical Position” (1800.1D.2.14.3.3.e)

Fatigue Management: NASA NPR 1800.1D

12 hour work schedules (1800.1D.2.14.3.11)

- 2 on/2 off, 3 on/3 off, 4 on/4 off
- 3 consecutive 12-hr shifts “are optimal”
- “Working more than 4 consecutive 12-hour shifts is associated with excessive fatigue and strongly discouraged”

Min allowable time off between shifts = 8 hr

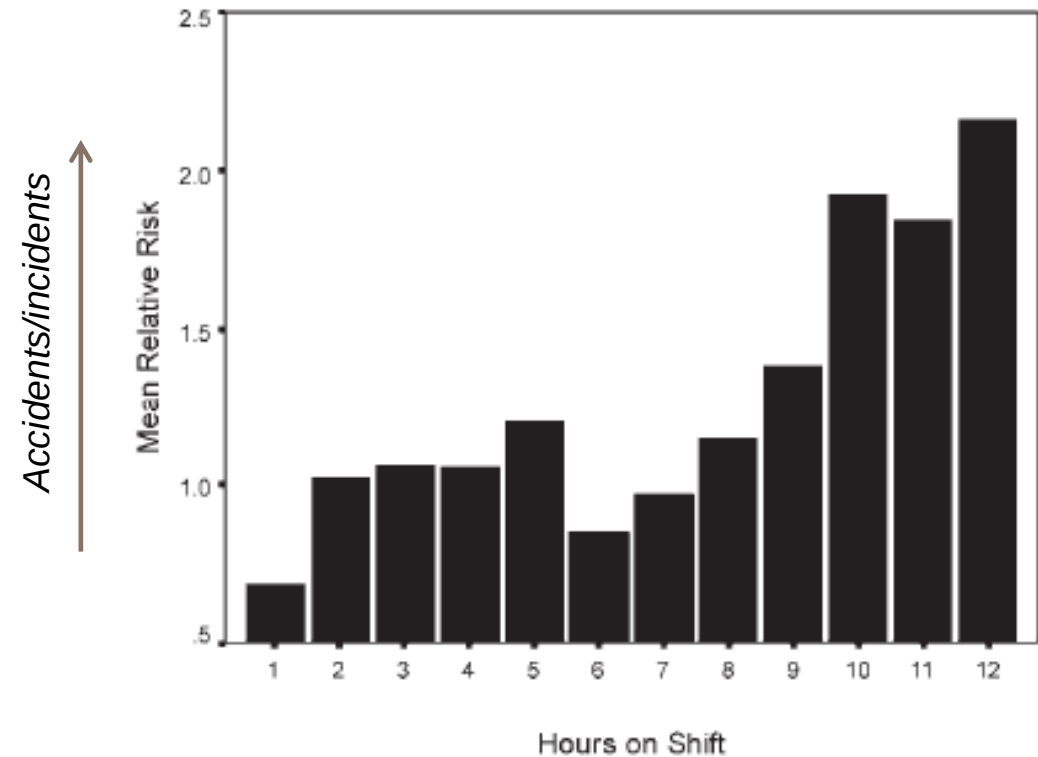
- 10 hr off duty preferred
- 12 hr or more “optimal to accommodate employee commute time and domestic and sleep needs” (1800.1.D.2.14.3.9)

Shift work schedules require additional time off between shifts

- Allow circadian rhythms time to adapt to changes in timing of work shifts
- Forward rotating: days > evening > night better for adaptation (1800.1.D.2.14.3.10)

Work Schedules

- Length of work periods
 - Hours awake
 - Time on task



Folkard & Tucker, 2003

Work Schedules

- Timing of work periods
 - Circadian nadir (night)
 - Early morning starts
 - Plan for critical tasks
 - Task rotation

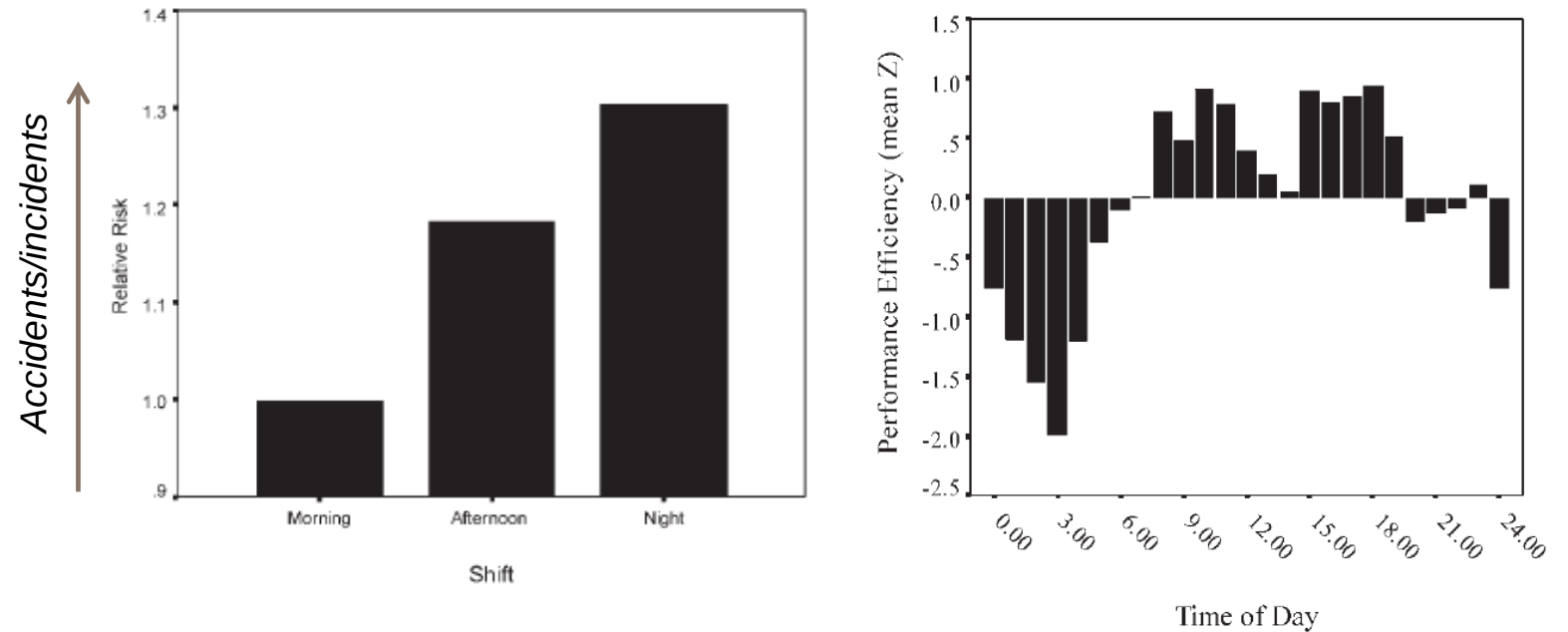
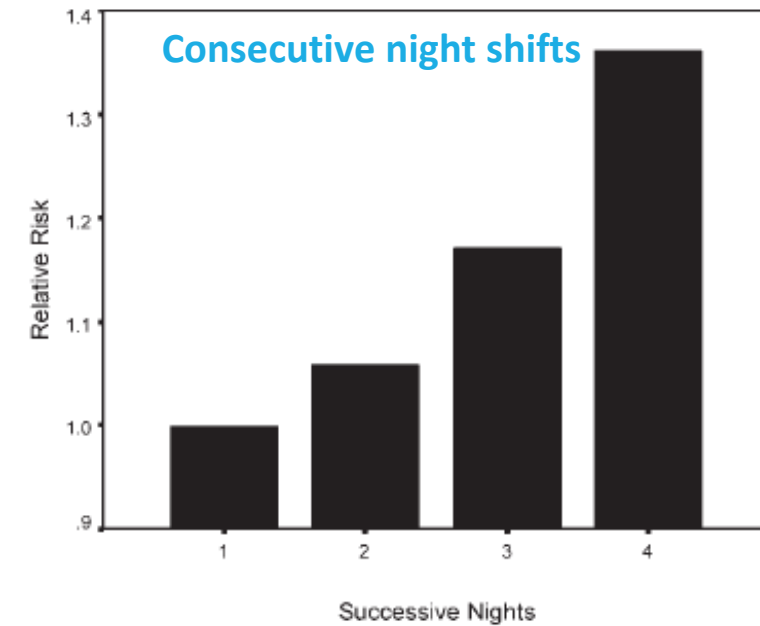
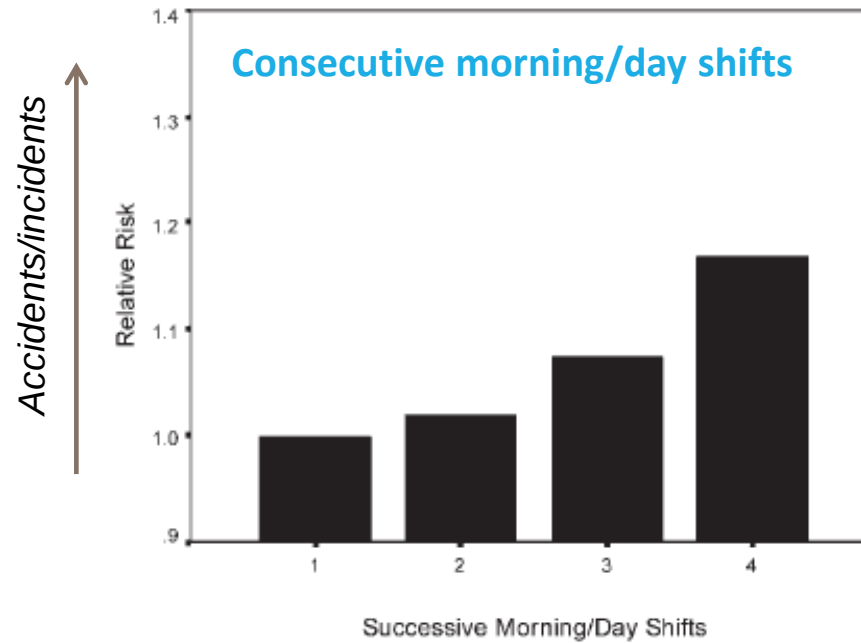


Figure 1. Industrial performance efficiency over the 24 h day.

Folkard & Tucker, 2003

Work Schedules

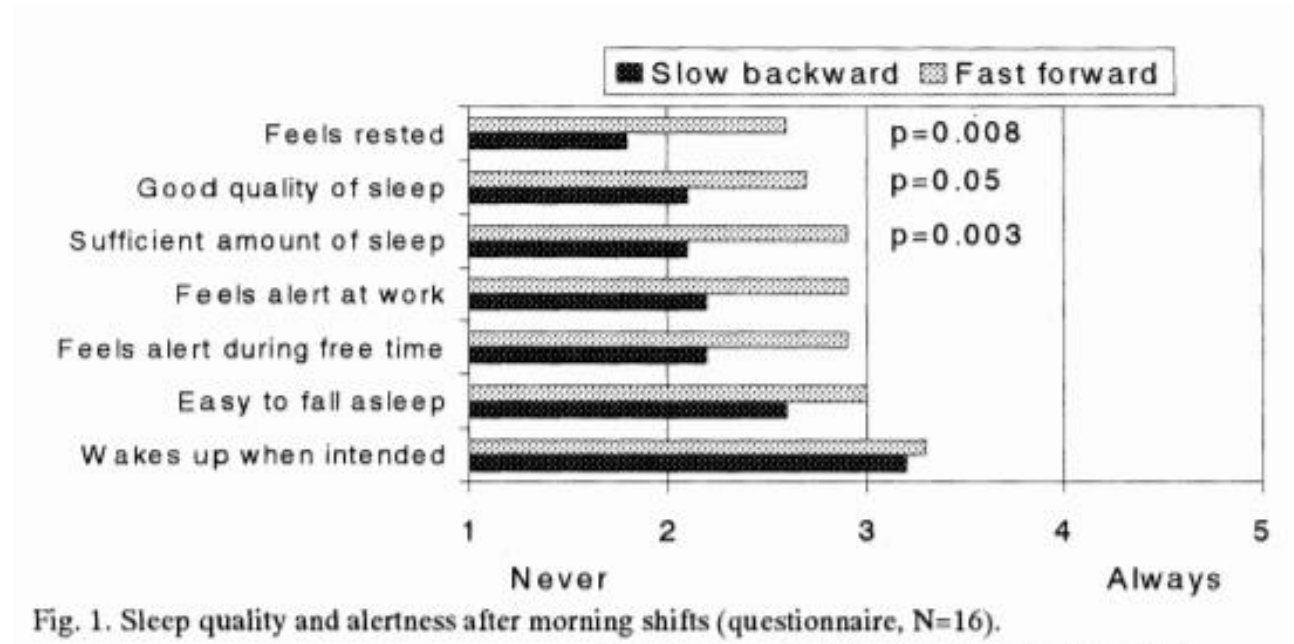
- Consecutive work periods
 - Chronic sleep restriction
 - Cumulative workload



Folkard & Tucker, 2003

Work Schedules

- Rotation of work periods
 - Forward rotation in sync with clock
 - Circadian adaptation is gradual



Hakola & Härmä, 2001

Work Schedules

- Overtime/work extensions
 - Extended hours awake
 - Extended time on task
 - Chronic sleep restriction
 - Cumulative workload

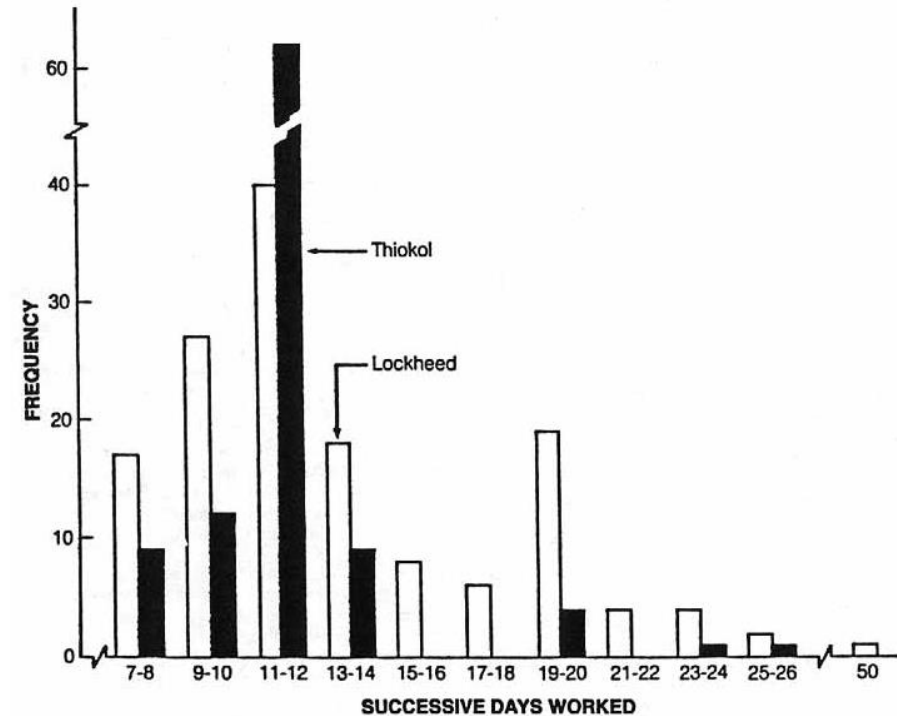
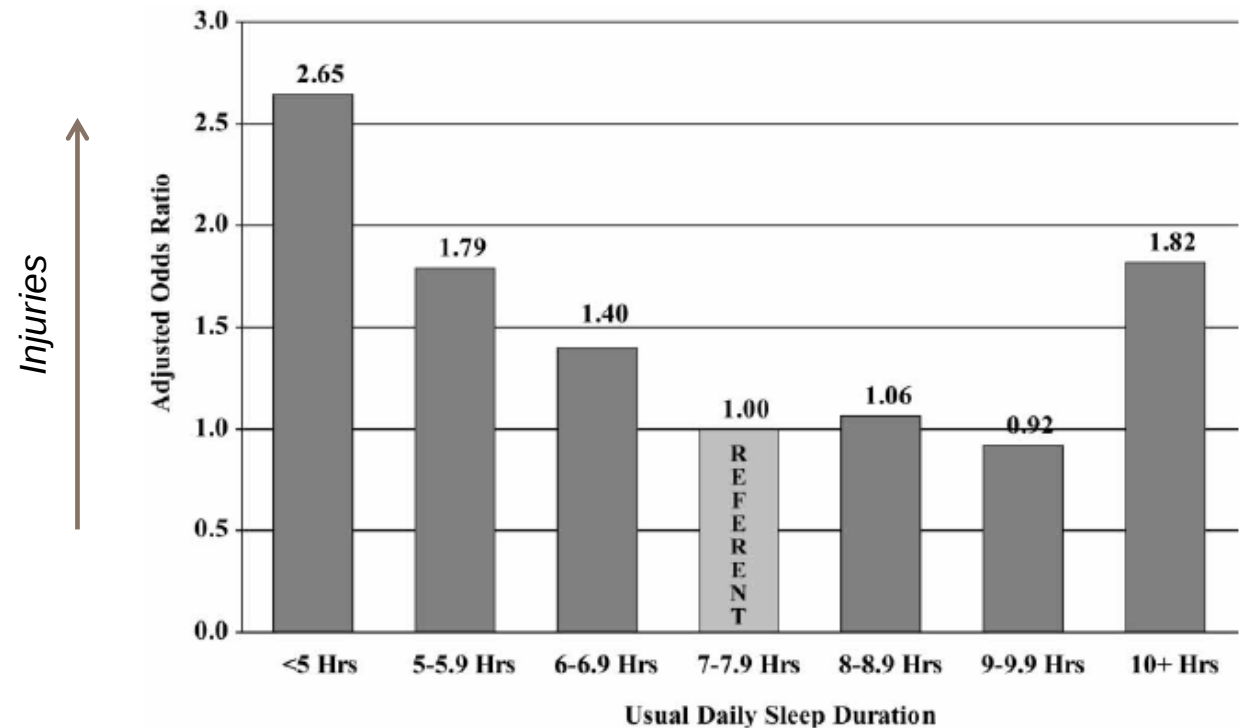


Figure 1—Incidence of more than six consecutive workdays among a group of Lockheed (N = 93) and Thiokol (N = 48) shiftworkers at Kennedy Space Center. Time period of sample varies from seven to ten weeks extending from October 26, 1985 to January 24, 1986.

*Report of the Presidential Commission on the Space Shuttle Challenger Accident –
Volume 2: Appendix G*

Work Schedules

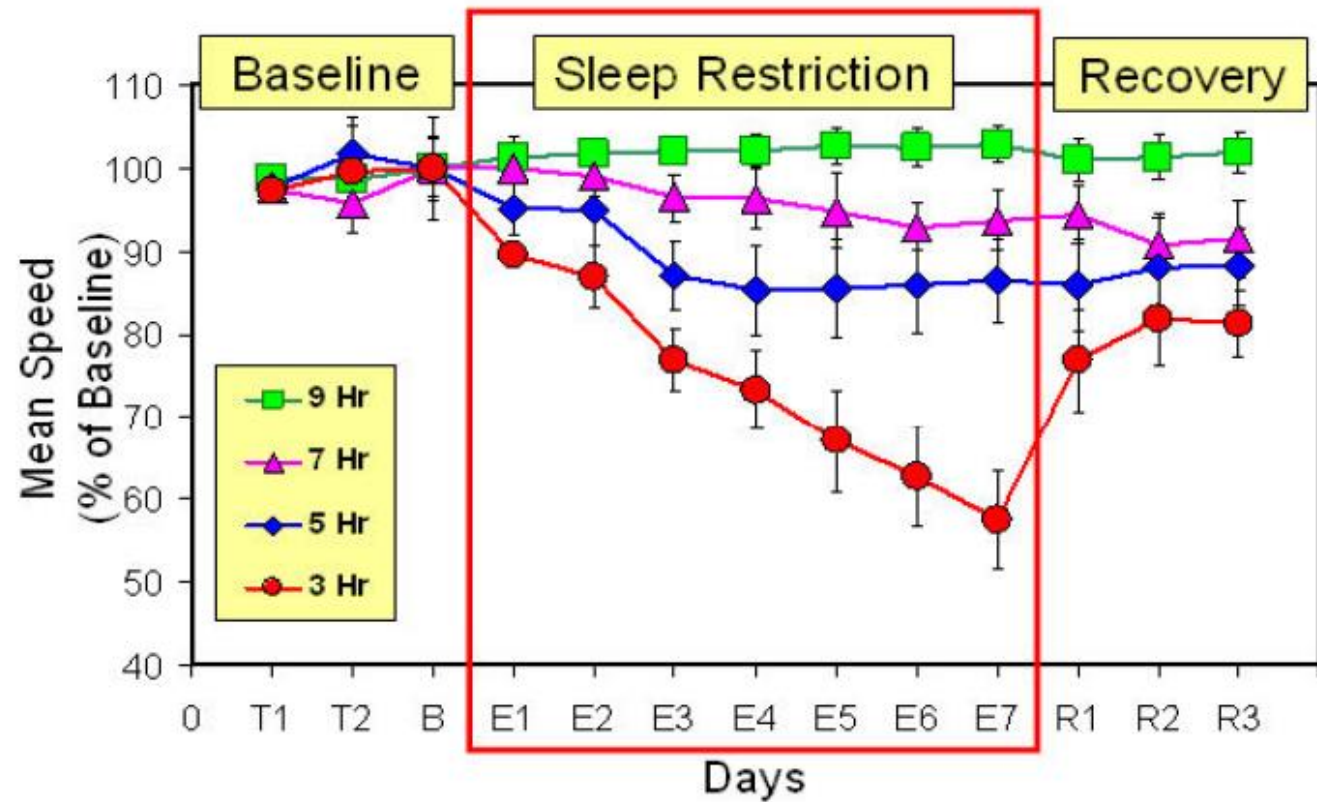
- Length and timing of off-duty periods
 - Prioritize sleep opportunities
 - Manage acute sleep loss
 - Nighttime sleep quality/quantity better



Lombardi, et al 2010

Work Schedules

- Recovery off-duty periods
 - Prioritize sleep opportunities
 - Manage chronic sleep loss



Adapted from Belenky, et al 2003

Work Schedules

- Regular breaks
 - Shorter, more often may provide benefit
 - Manage time on task/workload

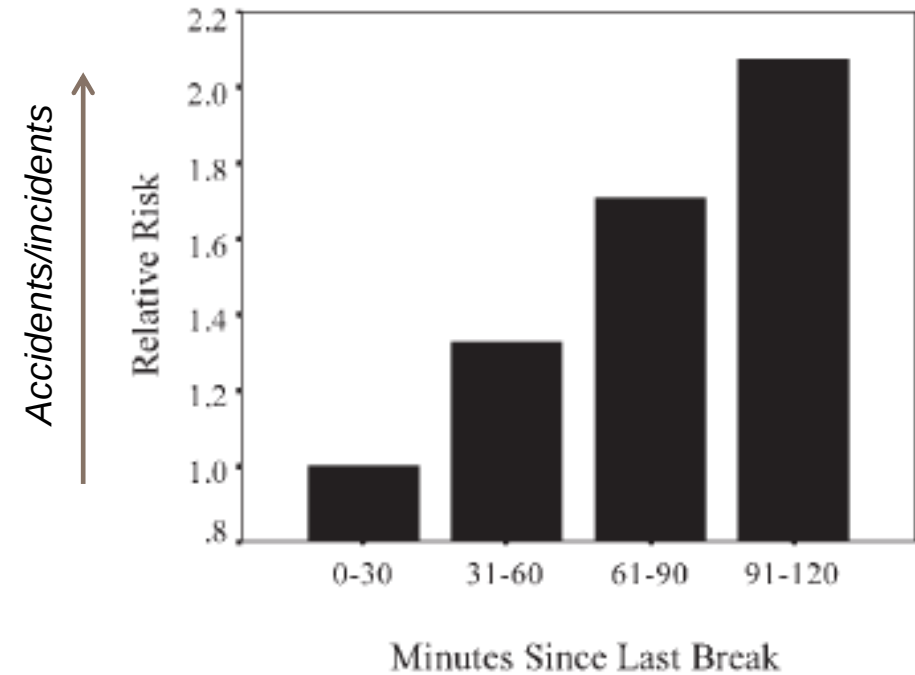


Figure 7. The trend in relative risk between breaks (from [30]).

Folkard & Tucker, 2003

Fatigue Management: Personal Strategies

**How to get
quality rest**

Sleep hygiene

**How to stay
alert on the job**

Fatigue countermeasures

Fatigue Management: Personal Strategies

- Sleep and naps
- Caffeine
- Light
- Exercise/physical activity
- Diet
- Family life

Fatigue Management: Good Sleep Habits

- Pre-sleep routine
 - Control the environment
 - Dark, cool, quiet
 - Keep work/stress out of the bedroom
 - Avoid bright/blue light before bed
 - Avoid caffeine/alcohol/nicotine
 - Tell household your schedule



Photo by Victoria Heath on Unsplash

Fatigue Management: Napping

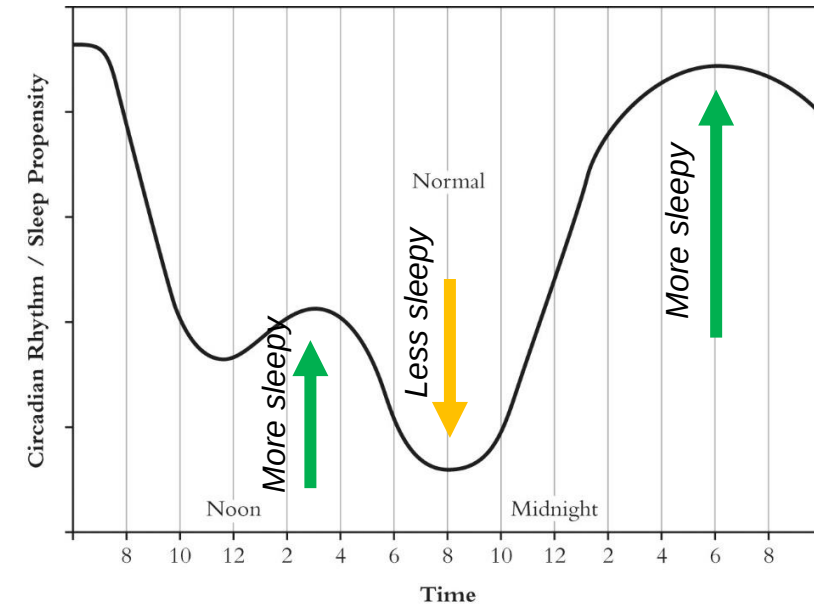
- Naps are best countermeasure to fatigue/sleep loss
- Longer naps provide longer benefits
- Short naps can be beneficial
- Benefits of nap depend on:
 - Duration and quality of the sleep
 - Timing
 - Prior sleep/wake history



Photo by [Andrew Seaman](#) on [Unsplash](#)

Fatigue Management: Napping

- Timing of naps
 - Use afternoon 'dip' prior to night shift
 - In morning when coming off night shift
- Consider use of eye masks, white noise, ear plugs, alarm
- Allow wake up time, minimize sleep inertia



Broughton, 1994

Fatigue Management: Caffeine

- Plan timing: use strategically
- Can be effective short-term
- Improves alertness, performance
- Downsides:
 - Tolerance levels/effectiveness vary
 - Half-life up to ~5 hr
 - Ineffective for extreme circumstances
 - Disturb sleep if too close



Photo by [Estela Shaddix](#) on [Unsplash](#)

Fatigue Management: Planning

- Try different strategies to determine what works best for you
- Effectiveness of strategies will vary by individual
- Plan according to:
 - Type of shift worked
 - Consecutive days/nights worked
 - Working extended hours
 - Quality of last sleep period



Photo by [Glenn Carstens-Peters](#) on [Unsplash](#)

Fatigue Management: Summary

- Fatigue can arise due to multiple factors
 - Acute sleep loss
 - Chronic sleep loss
 - Circadian misalignment
 - Hours awake
- Fatigue can lead to impaired performance and increased safety risks

Fatigue Management: Summary

- Fatigue management in the workplace requires awareness and responsibility from all participants
- Prioritize sleep during off-duty periods
- Practice good sleep habits
- Utilize fatigue countermeasures strategies that work best for you and for the work time at which it is applied
- Evaluate and change strategies as needed

“Although neither man was really tired after the first half of the picture-snapping, Conrad considered closing the hatch and resting until the next night pass. He asked the Hawaii CapCom if there was enough oxygen. The answer was yes. But the skies were clear over the United States, and they might want to take more pictures there. In that case, said Conrad, the hatch would stay open. Soon the crew marveled at the view of their home area-Houston. They passed quietly across Florida and out over the Atlantic with nothing to do. Suddenly, Gordon broke the silence to announce

that they had just taken a catnap. ‘There we were. . . , he was asleep hanging out the hatch on his tether and I was asleep sitting inside the spacecraft,’ Conrad reported. ‘That's a first,’ John Young answered, ‘first time sleeping in a vacuum.’”



http://www.nasa.gov/sites/default/files/styles/1x1_cardfeed/public/images/139573main_image_feature_470_vs_full.jpg



Thank you!

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