16.400/453J

Human Factors Engineering

Fatigue and Circadian Rhythms

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Lecture 19

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Outline

- Situations where fatigue is a factor
- Effects of fatigue
- Sleep
  - Components
  - Circadian rhythm
  - Stages
- Causes of fatigue
- Ways to measure fatigue
- Prevention methods
- My research!

Situations where fatigue is a factor

- Driving
- Shift work
- Aviation
- Astronauts
- School/tests
- Sports
- Jet lag
- Medical residents
- Commercial truck drivers
- Others?

Effects of fatigue – lower level

- Slower reaction times
- Reduced response accuracy
- Attentional lapses
- Take longer to perform tasks
- More errors
- More unnecessary movements
- Less systematic exploration
- Poor judgment
- Omission of details
- Indifference to essentials
- Generally inadequate performance
- Increased distractibility
- Worse driving performance
  - More inappropriate line crossings
  - Increased braking distance
  - Increased speed deviation around the speed limit

Have you observed any of this in your projects?

Effects of fatigue – higher level

- Decreased executive attention and executive control
  - Ability to regulate perceptual and motor processes for goal-directed behavior
- Decreased working memory
- Decreased flexibility
- Sub-optimal planning
- Impaired decision making involving unexpected situations or circumstances
- Impaired innovation, ability to revise plans, ability to handle competing distractions
- Less effective communication
- Distinction between low level, automatic, skill-based task components like steering and high-priority, rule- or knowledge-based tasks like hazard avoidance
  - Which would you guess are more affected? Why?
- Extent of the effect varies between individuals

Effects of fatigue – practical

- 1 in every 5 serious motor vehicle injuries is related to driver fatigue
- 80,000 drivers fall asleep behind the wheel every day
- 250,000 accidents every year related to sleep
- Accidents due to sleepiness are estimated to cost the US economy over $56 billion annually
- Sleep deprivation is attributed to over 24,000 deaths per year
- Sleep deprivation leads to the loss of 52 million work days each year

Effects of fatigue – practical

- Fatigue-related impairment often expressed as “blood-alcohol equivalent”
- Only 18-24 hours of continuous wakefulness can cause performance decline ~BAC of 0.1% (legal driving limit is 0.08%)
- Effect of one week of chronic sleep debt (6 hours of sleep per night) = effect of one night with no sleep

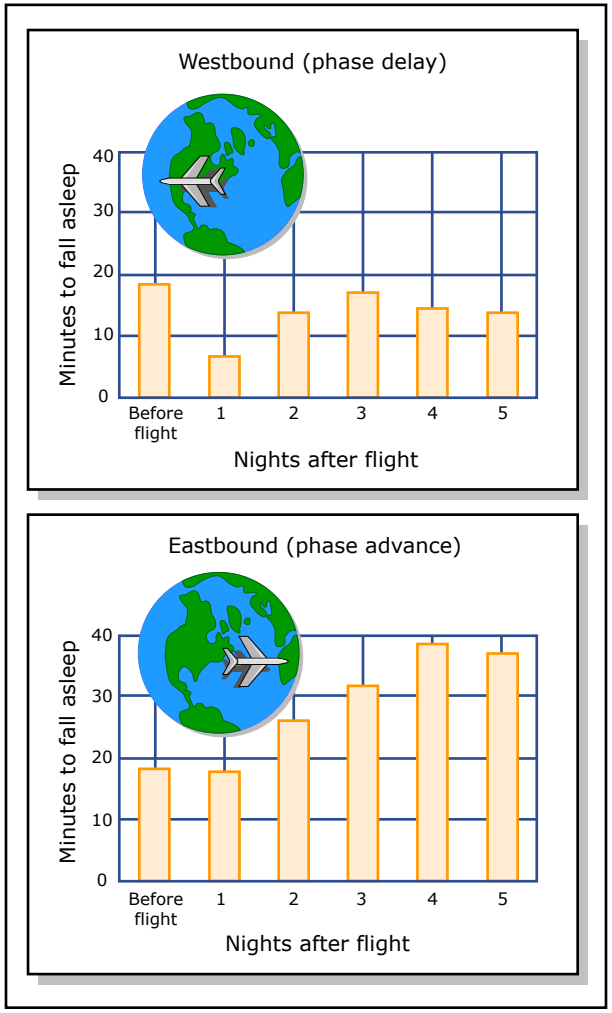
Effects of fatigue – aviation

- How many cases so far this semester have had fatigue as a contributing factor?
- FAA Work Limitations:
- ***No certificate holder*** *conducting domestic operations* ***may schedule*** *any flight crewmember and* ***no flight crewmember may accept*** *an assignment for flight time in scheduled air transportation or in other commercial flying* ***if that crewmember's total flight time in all commercial flying will exceed****:*
  - 1000 hours in any calendar year
  - 100 hours in any calendar month
  - 30 hours in any 7 consecutive days
  - 8 hours between required rest periods

US Code Title 14, part 121.471

Effects of fatigue – jet lag

- Shifting circadian rhythms
  - Phase advance shift
    - Shortened day
  - Phase delay shift
    - Lengthened day
- Jet-lag evidence suggests we can accommodate phase-delay changes more readily than phase-advance changes
  - (Nicholson et al., 1986)



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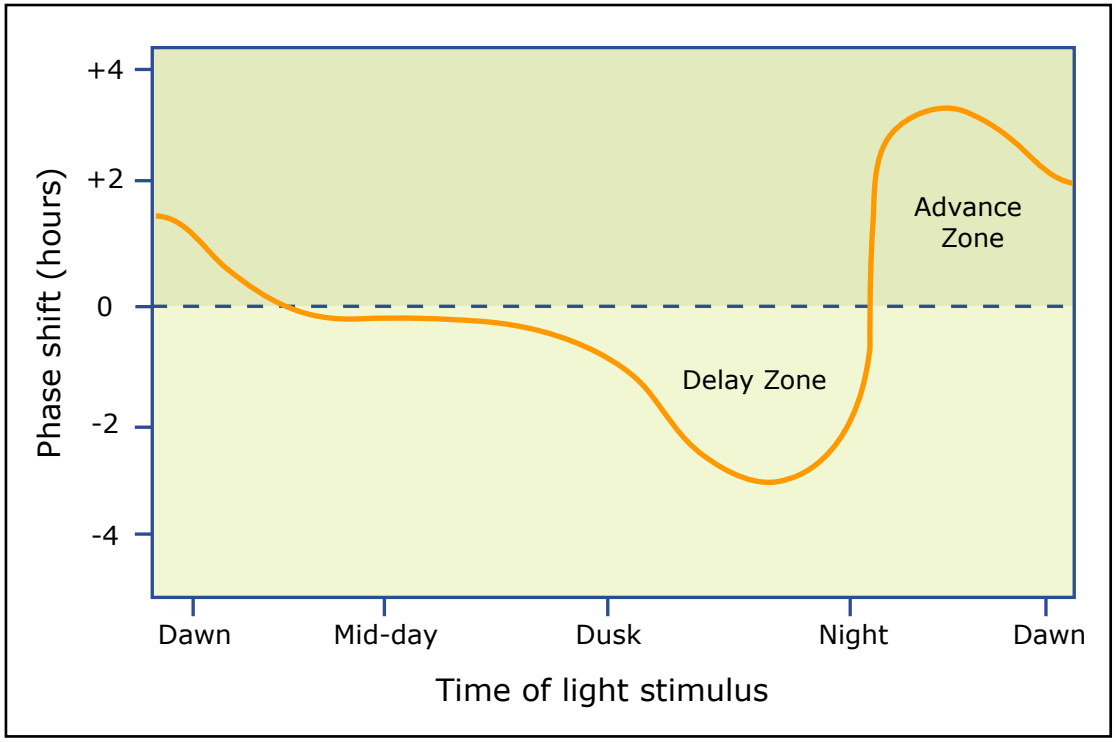
Effects of fatigue – jet lag

- Phase response curve due to light exposure to the eyes



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Effects of fatigue – space

- Astronauts average <6 hours of sleep per night
- Perform telerobotics tasks requiring vigilance, careful movements
- Mir-Progress 234 collision
- My research – more information later

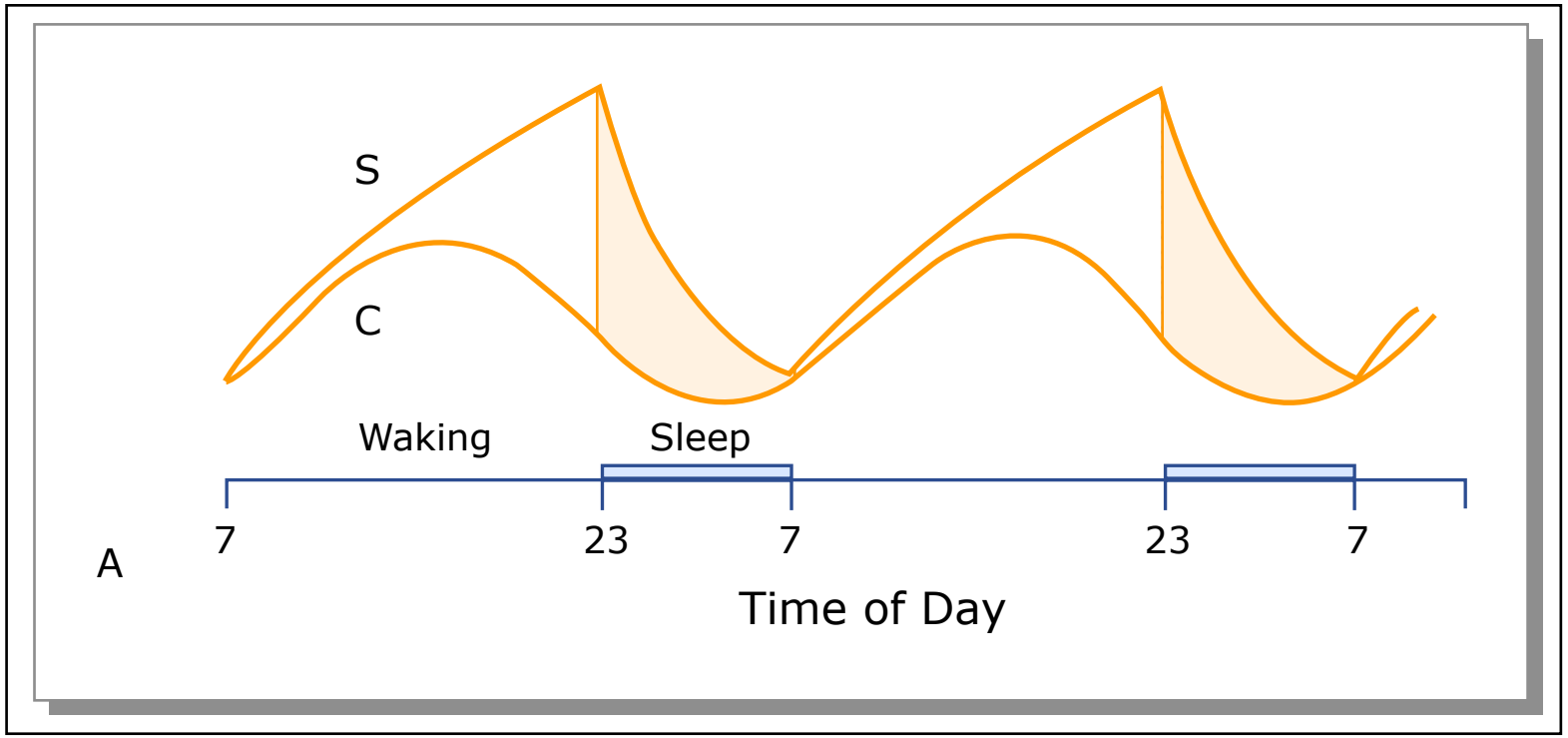
Effects of fatigue – trucking

- Federal Trucking Work Limitations
  - 10-hour maximum without break
  - 15-hour maximum without 8-hour break
  - 60 hours in any 7 consecutive days

Now that we're motivated…

Sleep cycle

- 2 processes – Sleep homeostat and circadian phase



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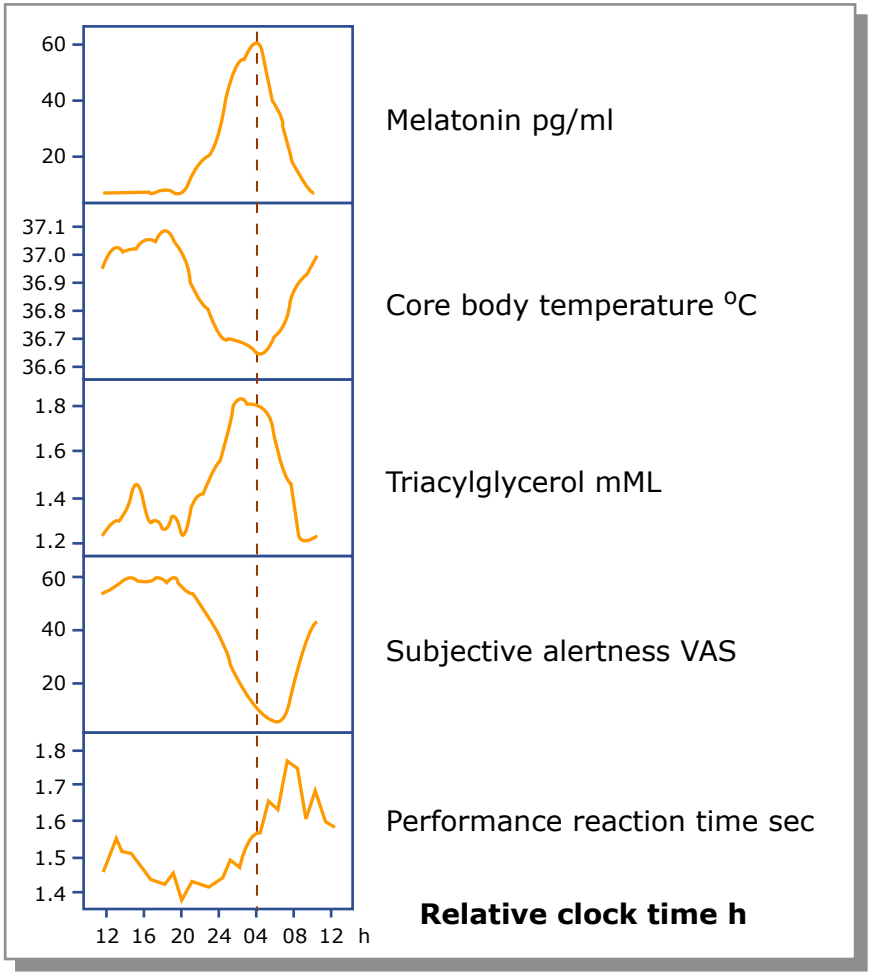
Circadian rhythm

- *Circa dies* – approximately one day
- Many bodily functions of humans and other animals fluctuate over the course of a day:
  - Body temperature
  - Heart rate
  - Blood pressure
  - Adrenaline production
  - Melatonin production
  - Urine production
  - Flicker-fusion frequency
  - Mental ability
  - Release of hormones into the bloodstream

Circadian rhythm



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Circadian Performance Simulation Software (CPSS) Demo

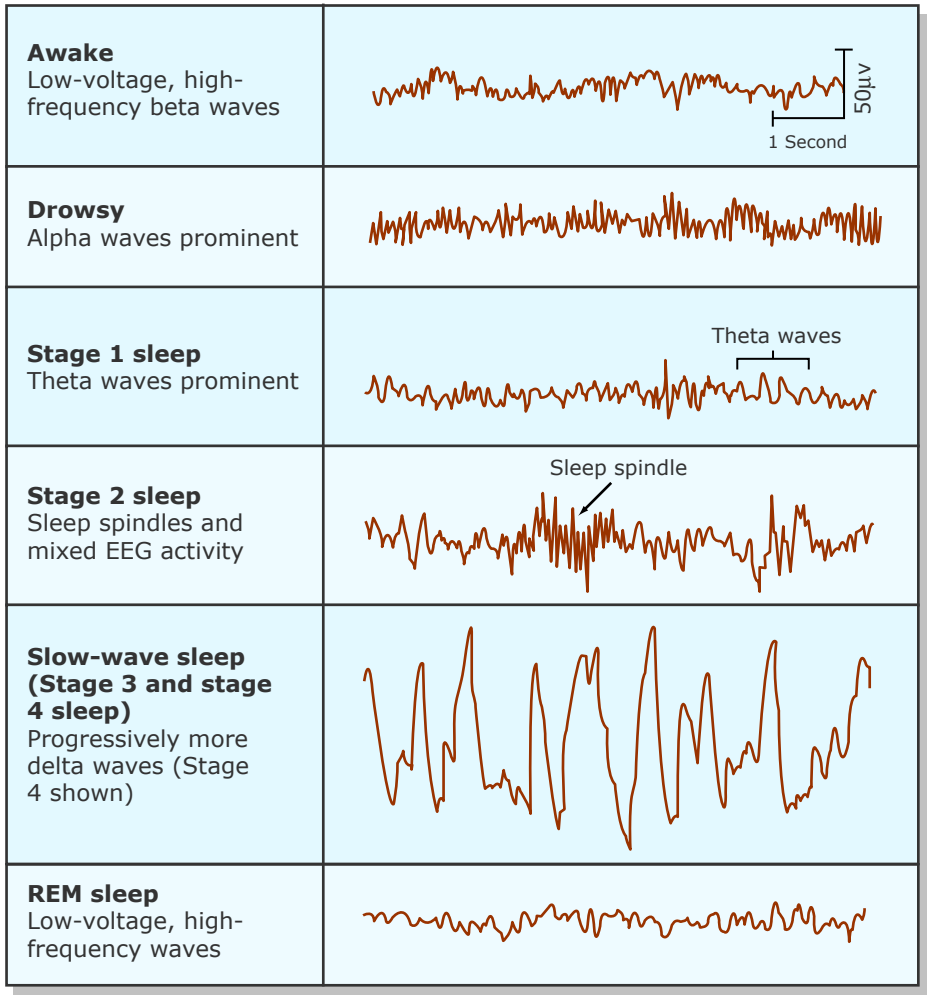
Screenshot of Circadian Performance Simulation Software removed due to copyright restrictions.

Why do we need sleep?

- Specific function of sleep is still uncertain
- Sufficient sleep critical to health and performance
- Age dependent requirements
  - Newborns: 15-17 hours
  - Healthy Adults: 6-8 hours/night (with considerable individual variations)
  - Elderly: can decrease significantly – or does it?
- Quality is cyclical, with many stages and depths

What happens when we're asleep?

In the Brain



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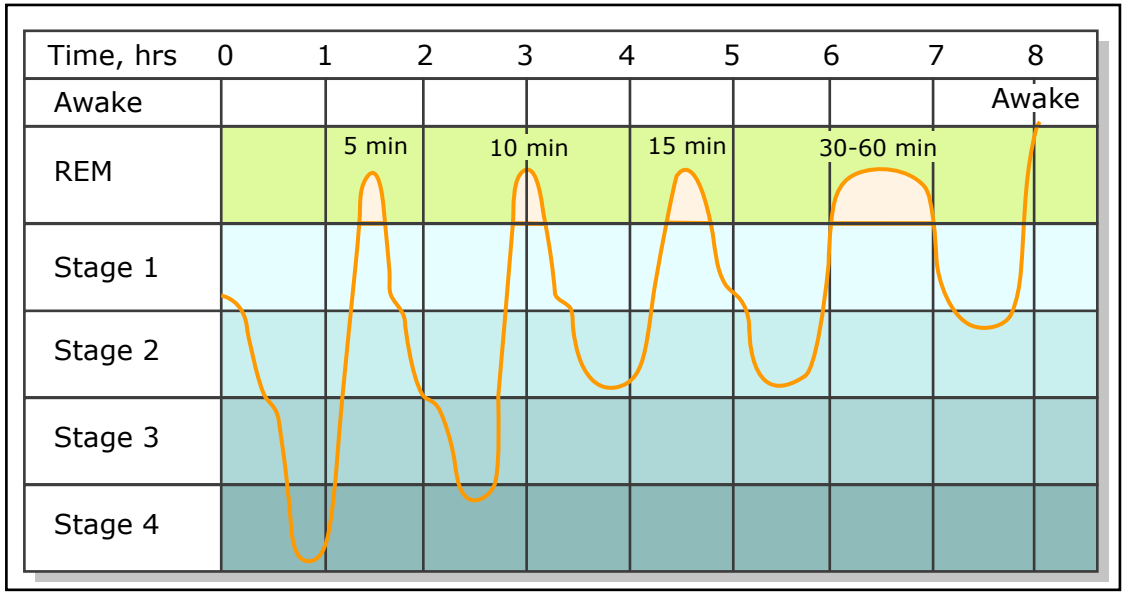
What happens when we're asleep?

- Stage 1
  - If awakened, people say they weren't asleep
  - Automatic behavior may occur in Stage 1 sleep
- Stage 2
  - Up to 50% of sleep time
  - Comes between periods of deep sleep and REM
- Stages 3-4
  - "Slow-Wave Sleep" (SWS)
  - Most vital for recuperation
  - Increases after intellectually challenging tasks
  - Most occurs during first half of sleep period
- REM
  - "Brain on, body off"; wakeful EEG pattern
  - Increased cerebral blood flow

Perception

What happens when we're asleep?

- Often ~4 descents into deep sleep, linked by intervening shallow periods
- 75% of SWS during first half of cycle
- 75% of REM during second half of cycle



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What happens without sleep?

- Slow Wave Sleep (Stage 3, 4) deprivation
  - Feeling unrested
  - Reduction in cognitive performance
- REM deprivation
  - Moodiness
  - Hypersensitivity
  - Inability to consolidate complex learning
  - REM appears to be important for psychological well-being
- Sleep debt
  - Cumulative increase over consecutive poor-sleep nights
  - Very poor relationship between self-reported sleepiness over the long term and objective measures of fatigue

Causes of fatigue

- How much sleep did you get last night?
- How much do you get on average?
- Lack of sleep
- Circadian phase
- Physical or mental exertion
- Time on task
- Workload
- Diet
- Stress

Ways to measure fatigue

- Objective
  - Electroencephalography (EEG)
  - Multiple Sleep Latency Test (MSLT)
  - Karolinska Drowsiness Test (KDT)
  - OptAlert
- Subjective
  - Karolinska Sleepiness Scale (KSS)
  - Epworth Sleepiness Scale (ESS)
  - Stanford Sleepiness Scale
  - Secondary tasks

Karolinska Sleepiness Scale

Please indicate your sleepiness during the 5 minutes before this rating by checking the box next to the appropriate number.
Use also the intermediate steps!

- ☐ 1 – very alert
- ☐ 2 –
- ☐ 3 – alert – normal level
- ☐ 4 –
- ☐ 5 – neither alert nor sleepy
- ☐ 6 –
- ☐ 7 – sleepy – but no effort to keep awake
- ☐ 8 –
- ☐ 9 – very sleepy, great effort to keep awake, fighting sleep

So you don’t want to be sleepy…

Prevention methods - Individual

- Set a schedule – go to bed and wake up at the same time every day
- Exercise about 5-6 hours before going to bed
- Avoid caffeine, nicotine, and alcohol
- Relax before bed
- Sleep until sunlight
- Don't lie in bed awake
- Control your room temperature

Intervention methods - Individual

- Intervention: caffeine
  - "World's most popular drug"
  - Mild central nervous system stimulant
  - 3.5 – 6 hr half-life
  - 250 mg: improves psychomotor function if sleep deprived
  - 500 mg: side effects without further functional improvement
  - Shakiness
  - Diuretic
  - Tachyphylaxis (desensitization)
  - Withdrawal headaches
  - Affects sleep latency (time to get to sleep) and sleep quality

Intervention methods - Individual

- Intervention: blue-enriched white light
  - Used on the ISS
  - Helps users feel more alert
  - Much shorter half-life than caffeine
  - Looks the same as regular white light
  - Doesn't affect sleep latency (time to get to sleep) or sleep quality
  - Requires special (expensive) equipment

Intervention methods - Individual

- Get more sleep!
- The only way to completely reverse physiological need for sleep is by sleeping
- Some sleep is better than no sleep
- Napping even 15 minutes can improve cognitive performance
  - "Stay Awake: Take a Break for Safety's Sake!"
- Poor sleep over time can lead to accumulated sleep debt

Prevention methods - Institutional

- Regulations on rest time
- Maximum hours permitted to work
  - Medical residents can work shifts up to 36 hours!
- Readiness-to-perform tests
- What else?

My research!

Research question:

How does sleepiness affect workload and performance on complex space robotics tasks?

My research - Procedure

- 1 training session
- 2 test sessions
  - One midday (noon), one night (10pm, wake at 4am)
- 2 types of robotics tasks
  - Autosequence
  - Track and capture
- 2 types of secondary tasks
  - Simple and complex
- Subjects screened for morningness

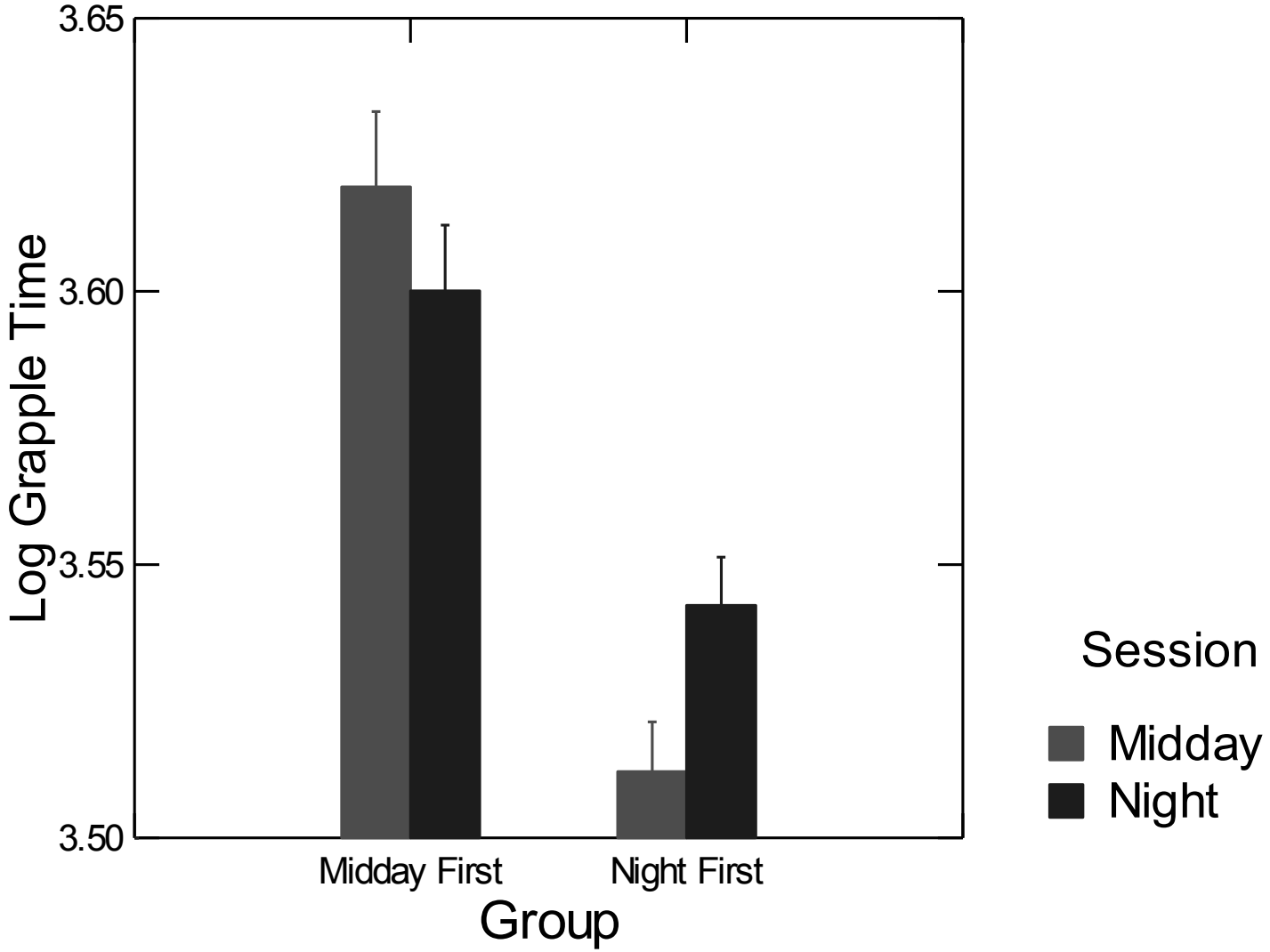
- What were the secondary tasks measuring?

My research – Experimental design

- Within-subjects test
- Randomly grouped into midday-first or night-first
- Side task type fully crossed with primary task type for all subjects
- Workload ratings
- Sleepiness ratings

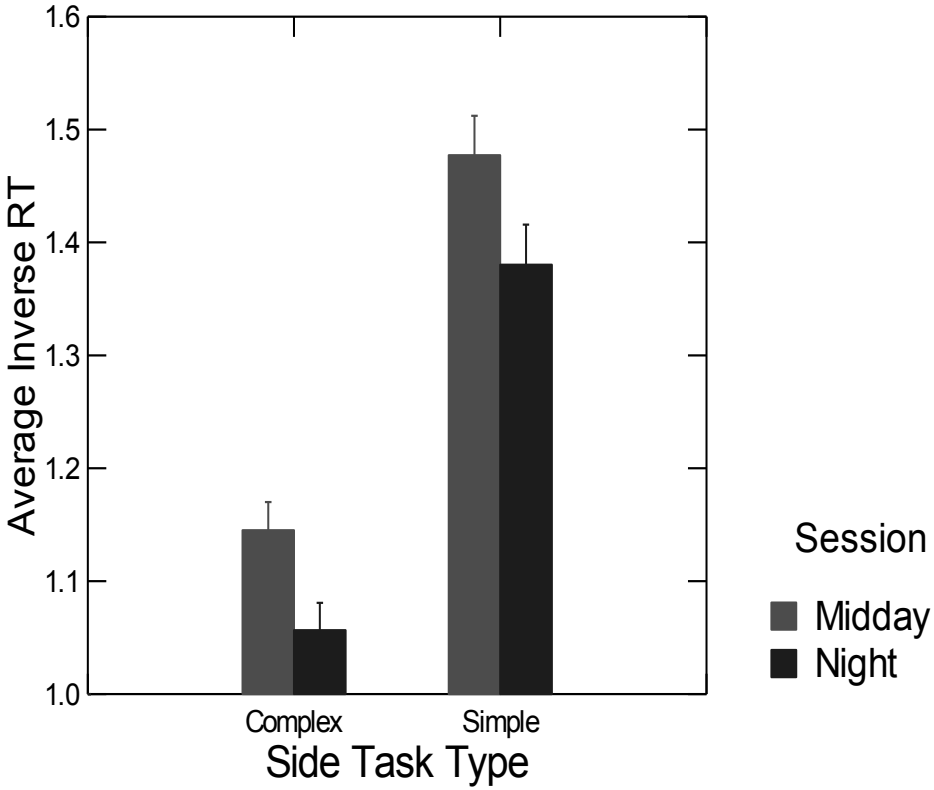
- What could I have done differently?

My research – Results

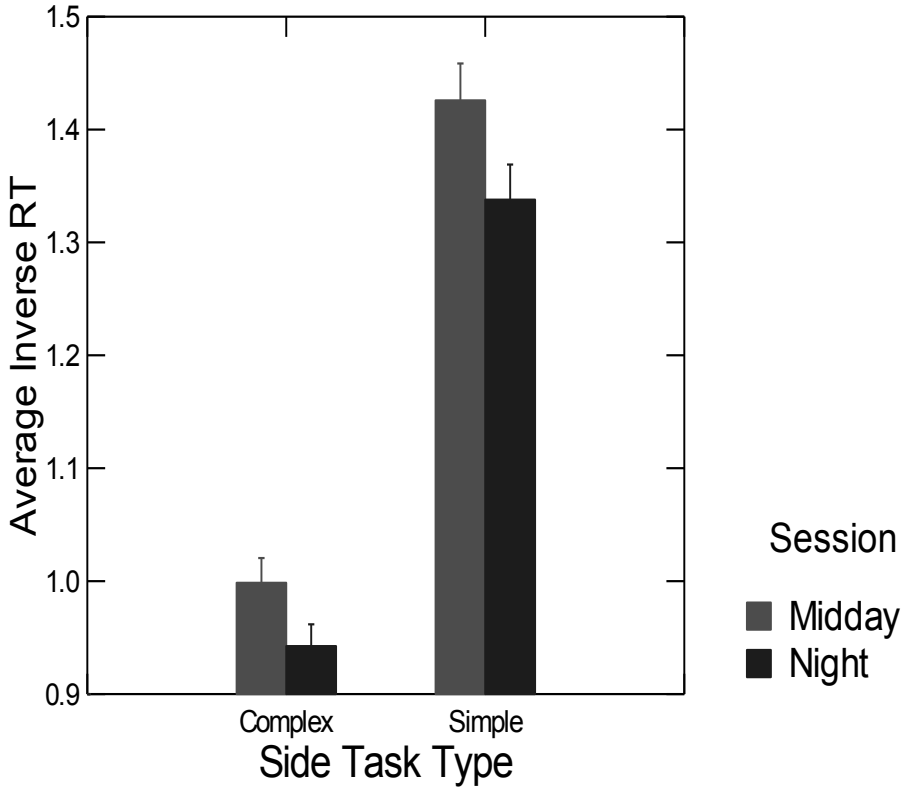


My research – Results

Track and Capture



Autosequence



Simple side task is more sensitive to sleepiness on autosequence.

Complex side task is more sensitive to sleepiness on track and capture.

My research – Conclusions

- Subjects were significantly sleepier at the night session
- No significant effect on autosequence primary task performance
- Combination of learning and time-of-day effects
- Different embedded secondary tasks are appropriate depending on the type of primary task

- What do you think?

Review

- Situations where fatigue is a factor
- Effects of fatigue
- Sleep
  - Components
  - Circadian rhythm
  - Stages
- Drivers of fatigue
- Ways to measure fatigue
- Prevention methods
- My research! – not on the test ☺

Questions?

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Fall 2011