Sleep and Performance

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Factors Affecting Performance

- Time Awake (sleep/wake history)
- Time of Day (circadian rhythm)
- Time on Task (shift length)
- Task Complexity
- Individual Differences in Response to
  - Time Awake
  - Time of Day
48 Hours of Total Sleep Deprivation: Effect on Complex Mental Operations

72 Hours of Total Sleep Deprivation: Effect on Complex Mental Operations Task
Time on Task Effects on PVT Speed over 38 Hours of Total Sleep Deprivation

Day 1

Day 2

85 Hours of Sleep Deprivation:
30-min Daily Nap & Complex Mental Operations

- Mean Performance (N=17)
- Cubic Spline
- Linear Regression

30-min Nap
Total Sleep Deprivation vs. Daily 30-min Nap: Effect on Complex Mental Operations

Throughput (Percent of Baseline)

Sleep Deprivation (Hours)

85 Hours of Sleep Deprivation: 30-min Daily Nap & Complex Mental Operations

- Mean Performance (N=17)
- Cubic Spline
- Linear Regression

PET Scans

Sleep Deprivation (Hours)
PET Study of Sleep Deprivation: Findings

Frontal areas are deactivated during Slow Wave Sleep.

Frontal areas remain deactivated during REM.

Frontal areas are re-activated only after awakening.

Positron Emission Tomography (PET) Study of Sleep

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Subjects, Number/Sleep Group, Time in Bed

- 66 commercial drivers
  - in good general health
  - non smokers
  - light caffeine users (2-4 cups/day)
- 16 women
  - mean age 39 (range 24-55)
- 50 men
  - mean age 37 (range 24-62)
- 3 hr sleep group
  - Time in bed: 0400-0700
  - n = 18
- 5 hr sleep group
  - Time in bed: 0200-0700
  - n = 16
- 7 hr sleep group
  - Time in bed: 2400-0700
  - n = 16
- 9 hr sleep group
  - Time in bed: 2200-0700
  - n = 16
Instrumented Volunteers

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Measures

• 24 hr. Polysomnography (EEG, EOG, EMG) (Oxford Medilog)
  - Sleep scoring
  - Sleep latency testing

• 24 hr. Actigraphy (Precision Control Design, Inc.)

• Psychomotor Vigilance Task (PVT)

• Driving Simulator (STI, Inc)

• Oculomotor Responses - Fitness Impairment Tester (FIT) (PMI, Inc.)

• WRAIR Performance Assessment Battery (PAB)

• Synthetic Work Task

• Stanford Sleepiness Scale

• Profile of Mood States
Mean Sleep, Baseline, Experimental Days, & Recovery

![Graph showing mean sleep, baseline, experimental days, and recovery.]

### Mean Sleep
- **Experimental Days**
  - 9 hr group - 7.9 hrs
  - 7 hr group - 6.3 hrs
  - 5 hr group - 4.7 hrs
  - 3 hr group - 2.9 hrs

### Amount of Sleep (Hrs)
- 9 HR
- 7 HR
- 5 HR
- 3 HR

### Day
- T2 B E1 E2 E3 E4 E5 E6 E7 R1 R2

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Effect of Partial Sleep Deprivation (Restricted Sleep) on PVT Performance

![Graph showing the effect of partial sleep deprivation on PVT performance.]

### Baseline
- Sleep Restriction
- Recovery

### Mean Speed (% of Baseline)
- 9 HR
- 7 HR
- 5 HR
- 3 HR
- 72 Hr TSD

### Day
- 0 T1 T2 B E1 E2 E3 E4 E5 E6 E7 R1 R2 R3
Psychomotor Vigilance Task (PVT)
Time on Task Effects @ 1200

Serial Addition Substraction
<table>
<thead>
<tr>
<th>Lane Standard Deviation</th>
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</thead>
<tbody>
<tr>
<td>Day</td>
</tr>
<tr>
<td>T1</td>
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Driving Simulator: Lane Tracking

Driving Simulator
Microsleeps and Accidents

- Microsleep –
  - the occurrence of theta in the absence of artifact
  - with a duration up to 15 s
  - Anything longer scored as R&K Stage 1 sleep
- Occurrence during the minute preceding the accident

- During the sleep restriction phase
  - No R&K Stage 1 Sleep
  - all groups - 33%
  - preceded by microsleep
  - 3 hr sleep group - 49%
  - 9 hr sleep group - 29%
Driving Simulator: Peripheral Attention Task

Driving Simulator: Average Speed Across Zones
Conclusion: Restructuring the Sleep Debt

- Sleep Debt - Restructured
  - As long as performance is degrading sleep debt is accumulating
  - Once performance stabilizes sleep debt no longer accrues
  - Sleep debt is paid off rapidly
- The brain adapts to sleep restriction by capping operational capacity
- This adaptation persists into recovery, restricting performance

- Sleep Debt – Traditional view
  - Sleep debt accumulates continuously, linearly
  - Sleep debt takes days, weeks, or months to pay off
Issues in Modeling

- Current models are simple one-quantity reservoir models
  - A single quantity depleting
  - The same quantity replenishing
  - Typically different functions govern depletion and replenishment
- Simple reservoir models cannot account for the effects of sleep deprivation and sleep restriction on performance
- The performance effects and neurobiology are distinct for surge vs. sustained operations
  - Surge operations (equate to acute, severe/total sleep deprivation)
  - Sustained operations (equate to chronic sleep restriction)

Sensors, Circuits, and Software Models in Real-World Application: The Sleep Watch

Sleep Performance Prediction Model Output

Activity Counts

A Nap

Sleep Scoring Algorithm Output
Sleep Performance Model Based on Leading Facts from Sleep Research

- Linear Decline during Waking
- Charging Function during Sleep
- Circadian Rhythm
- Combined (decline, charge, circadian)

Point of Contact

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