Sleep, Fatigue, and Performance

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The Earth at Night: The Problem of 24/7 Operations

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The 24-Hour Sleep/Wake Cycle

- 0000: Slow Wave
- 0600: REM
- 1200: Waking
Sleep-Related Factors Affecting Performance

• Time awake (sleep/wake history)
• Time of day (circadian rhythm)
• Time on task (~shift length; % of shift spent on task)
• Sleep inertia
• Individual differences in response to
  – Time awake
  – Time of day
  – Time on task
  – Sleep inertia
• Adaptation to restricted sleep
Components of Fatigue

Time Awake, Time of Day, Time on Task

PVT Speed (1/RT)

Clock Time

Sleep Deprivation - Day 1
Sleep Deprivation - Day 2

Adapted from Wesensten et al., 2004
Consequences of Sleep Restriction and Sleep Deprivation

• Short term
  – Minutes, hours
  – Error, accident, catastrophe

• Mid-term
  – Weeks, months, years
  – Bad planning, inadequate strategizing, poor life decisions

• Long-term
  – Years
  – Overweight/obesity, Type II Diabetes, Sleep Disorder Breathing, Metabolic Syndrome, etc.

• Fatigue and Health-Related Risk Management
Fatigue Risk Management
(adapted from Dawson and McCulloch, 2005)

- Three-tiered defense-in-depth to prevent fatigue related errors, incidents, and accidents
- Tier 1 – Does system of shift timing and duration allow for adequate opportunity for sleep?
  - Computer-based rostering
  - Predictive Modeling
- Tier 2 – Do employees take advantage of the sleep opportunity?
  - Self-report
  - Wrist-worn actigraph (sleep watch)
- Tier 3 – In the workplace, do they maintain adequate alertness and performance?
  - Self-report & co-worker report
  - Palm Pilot Psychomotor Vigilance Task (PVT)
  - Embedded performance metrics
Tools for Field Studies

- Sleep watch actigraph to objectively measure total sleep time
- Palm OS – base Psychomotor Vigilance Task (PVT) to objectively measure total sleep time

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Objective Measurement of Sleep and Prediction of Performance

The Sleep Watch Actigraph and Integration with Mathematical Modelling
Actigraphy and Sleep Scoring

Nocturnal Awakening

File: GB1.amr(ZCM)
Scale: 456
Algorithm: Cole-Kripke (rescore)

Nap
Performance Prediction

Nocturnal Awakening

Nap

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Psychomotor Vigilance Task and Embedded Metrics
Sleep Restriction and Performance: A Sleep Dose/Response Study

8 hrs in bed
3, 5, 7, 9 hrs in bed
8 hrs in bed

Adaptation Phase
Experimental Phase
Recovery Phase
Release from study

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Driving Simulator
Driving Simulator – RMS Lane Deviation: An Embedded Performance Metric

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The Harvard Intervention Study

Effect of Shift Timing and Duration on Sleep and Superimposed and Embedded Performance Metrics

A Case Example of Fatigue Risk Management
Traditional vs. Intervention Schedule

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Duration of Work

Duration of Sleep

<table>
<thead>
<tr>
<th></th>
<th>Traditional</th>
<th>Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hours/Week</td>
<td>45.9 +/- 5.9</td>
<td>51.7 +/- 6.0</td>
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<tr>
<td>Hours/Day</td>
<td>6.6 +/- 0.8</td>
<td>7.4 +/- 0.9</td>
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</tbody>
</table>

Limiting Work Hours: Attentional Failures

## Limiting Work Hours: Effect on Serious Medical Errors


<table>
<thead>
<tr>
<th>Variable</th>
<th>Traditional Schedule</th>
<th>Intervention Schedule</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serious medical errors made by interns</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Serious medical errors</td>
<td>176 (136.0)</td>
<td>91 (100.1)</td>
<td>&lt;0.001</td>
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<tr>
<td>Preventable adverse events</td>
<td>27 (20.9)</td>
<td>15 (16.5)</td>
<td>0.21</td>
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<tr>
<td>Intercepted serious errors</td>
<td>91 (70.3)</td>
<td>50 (55.0)</td>
<td>0.02</td>
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<tr>
<td>Nonintercepted serious errors</td>
<td>58 (44.8)</td>
<td>26 (28.6)</td>
<td>&lt;0.001</td>
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<tr>
<td>Types of serious medical errors made by interns</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medication</td>
<td>129 (99.7)</td>
<td>75 (82.5)</td>
<td>0.03</td>
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<tr>
<td>Procedural</td>
<td>11 (8.5)</td>
<td>6 (6.6)</td>
<td>0.34</td>
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<tr>
<td>Diagnostic</td>
<td>24 (18.6)</td>
<td>3 (3.3)</td>
<td>&lt;0.001</td>
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<tr>
<td>Other</td>
<td>12 (9.3)</td>
<td>7 (7.7)</td>
<td>0.47</td>
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</tbody>
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