Sleep in High Stress Occupations

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Disclosure

I have no relevant financial relationship with any commercial interest to disclose.
Physiological Limits to Performance

• Circadian time of day
• Number of hours awake (acute sleep debt)
• Cumulative sleep debt (chronic sleep debt)
• Time since awakening (sleep inertia)

Modifiers of Physiological Response
• Individual differences in susceptibility to sleep loss
• Sleep disorders
Physiological Limits to Performance

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Modifiers of Physiological Response
• Individual differences in susceptibility to sleep loss
• Sleep disorders
Circadian Nadir = Poorest Performance

Dijk and Lockley, JAP 2002
Wake Maintenance Zone = Peak in Wakefulness

Dijk and Lockley, JAP 2002
Wide Awake on the Sea of Tranquillity

This installment of Science@NASA’s Apollo Chronicles explains why Neil Armstrong and Buzz Aldrin couldn’t fall asleep in the Sea of Tranquillity.

Neil Armstrong was supposed to be asleep. The moonwalking was done. The moon rocks were stowed away. His ship was ready for departure. In just a few hours, the Eagle’s ascent module would blast off the Moon, something no ship had ever done before, and Neil needed his wits about him. He curled up on the Eagle’s engine cover and closed his eyes.

But he could not sleep.

Neither could Buzz Aldrin. In the cramped lander, Buzz had the sweet spot, the floor. He stretched out as much as he could in his spacesuit and closed his eyes. Nothing happened. On a day like this, sleep was out of the question.

The Eagle was not a sleepy place. The tiny cabin was noisy with pumps and bright with warning lights that couldn’t be dimmed. Even the window shades were glowing, illuminated by intense sunshine outside. "After I got into my sleep stage and all settled down, I realized there was something else [bothering me]," said Armstrong. The Eagle had an optical telescope sticking out periscope-style. "Earth was shining right through the telescope into my eye. It was like a light bulb."

To get some relief, they closed the helmets of their spacesuits. It was quiet inside and they "wouldn’t be breathing all the dust" they had tramped in after the moon walk, said Aldrin. Alas, it didn’t work. The suit’s cooling systems, so necessary out on the scorching lunar surface, were too cold for sleeping inside the Eagle. The best Aldrin managed was a "couple hours of mentally fitful drowsing." Armstrong simply stayed awake.
Wide Awake on the Sea of Tranquility

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CREW PARTICIPATION
n = 80 Missions
n = 60 Subjects
n = 26 Flights

PREFLIGHT:
• 2 weeks at L-90
  – “Normal sleep”
• L-11 through launch
  – Shift in sleep/wake cycle

THROUGHOUT SPACEFLIGHT

MISSION

POSTFLIGHT:
• R+0 through R+7
### Self-Reported Causes of Sleep Disruption in Space

<table>
<thead>
<tr>
<th>Most common reported causes of sleep disturbance</th>
<th>Percentage of disturbed nights$^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L-90</td>
</tr>
<tr>
<td>Voids</td>
<td>79 (54.9)</td>
</tr>
<tr>
<td>Noise</td>
<td>30 (20.8)</td>
</tr>
<tr>
<td>Too cold</td>
<td>6 (4.2)</td>
</tr>
<tr>
<td>Other crewmembers</td>
<td>0 (0.0)</td>
</tr>
<tr>
<td>Too hot</td>
<td>8 (5.6)</td>
</tr>
<tr>
<td>Mission duties</td>
<td>8 (5.6)</td>
</tr>
<tr>
<td>Physical discomfort</td>
<td>14 (9.7)</td>
</tr>
</tbody>
</table>

Sleep Duration by Study Condition

Barger et al. Lancet Neuro, 2014
## Sleep Outcomes by Sleep Medication Use and Non-use

<table>
<thead>
<tr>
<th></th>
<th>Nights without sleep-promoting drugs</th>
<th>Nights with sleep-promoting drugs</th>
<th>Difference between nights with and without drugs (95% CI)</th>
<th>p value</th>
<th>For difference (shuttle)</th>
<th>For difference (ISS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total sleep time</td>
<td>Shuttle (n=252)</td>
<td>ISS (n=255)</td>
<td>Shuttle (n=355)</td>
<td>-0.19</td>
<td>0.00808</td>
<td>0.3884</td>
</tr>
<tr>
<td></td>
<td>(0.88)</td>
<td>(0.90)</td>
<td>(0.57)</td>
<td>(0.86)</td>
<td>(0.01 to 0.38)</td>
<td>(0.50 to 1.68)</td>
</tr>
<tr>
<td>Sleep efficiency</td>
<td>Shuttle (n=252)</td>
<td>ISS (n=255)</td>
<td>Shuttle (n=355)</td>
<td>1.3</td>
<td>0.0038</td>
<td>0.4227</td>
</tr>
<tr>
<td></td>
<td>(7.3)</td>
<td>(9.8)</td>
<td>(5.6)</td>
<td>(5.5)</td>
<td>(0.2 to 2.8)</td>
<td>(2.2 to 9.4)</td>
</tr>
<tr>
<td>Sleep latency*</td>
<td>Shuttle (n=252)</td>
<td>ISS (n=255)</td>
<td>Shuttle (n=355)</td>
<td>-11.01</td>
<td>0.0013</td>
<td>0.0254</td>
</tr>
<tr>
<td></td>
<td>(25.90)</td>
<td>(18.52)</td>
<td>(16.20)</td>
<td>(7.72)</td>
<td>(19.43 to 2.60)</td>
<td>(2.14 to 4.47)</td>
</tr>
<tr>
<td>Sleep quality</td>
<td>Shuttle (n=252)</td>
<td>ISS (n=255)</td>
<td>Shuttle (n=355)</td>
<td>8.59</td>
<td>0.0419</td>
<td>0.5168</td>
</tr>
<tr>
<td></td>
<td>(20.39)</td>
<td>(16.35)</td>
<td>(13.91)</td>
<td>(7.92)</td>
<td>(3.32 to 13.87)</td>
<td>(3.14 to 17.48)</td>
</tr>
<tr>
<td>Alertness</td>
<td>Shuttle (n=252)</td>
<td>ISS (n=255)</td>
<td>Shuttle (n=355)</td>
<td>5.22</td>
<td>0.1909</td>
<td>0.1837</td>
</tr>
<tr>
<td></td>
<td>(17.74)</td>
<td>(24.40)</td>
<td>(15.98)</td>
<td>(3.97)</td>
<td>(1.57 to 8.87)</td>
<td>(3.93 to 9.87)</td>
</tr>
<tr>
<td>Disturbed sleep</td>
<td>Shuttle (n=252)</td>
<td>ISS (n=255)</td>
<td>Shuttle (n=355)</td>
<td>-14.1</td>
<td>0.0525</td>
<td>0.1119</td>
</tr>
<tr>
<td></td>
<td>(36-5)</td>
<td>(25-2)</td>
<td>(34-4)</td>
<td>(43.0)</td>
<td>(23-6 to 4-5)</td>
<td>(32-4 to 48.7)</td>
</tr>
</tbody>
</table>

Data are mean (SD), unless otherwise indicated. n represents the number of nights, whereas N is number of crew members. Mean, SD, mean difference, and 95% CI are based on raw data and p values are from statistical models. Data are mean (SD), based on raw data, or number (%); p values are from statistical models. * We excluded latency times of > 240 min. † Ratings are from a 100 mm non-numeric visual analog scale. ISS = International Space Station. EVA = extra-vehicular activity.

Table 3: Sleep outcomes on nights aboard space shuttle and ISS missions with and without sleep-promoting drugs

Barger et al. Lancet Neuro, 2014
Consequences of Circadian Misalignment

• 13% of nights misaligned during the L-11 block
• 20% of nights misaligned during flight
  • 27% of nights misaligned during vehicle/ISS docking
  • Sleep medication reported on 24% of misaligned nights and 11% of aligned nights

Flynn-Evans et al., In preparation, 2014
## Consequences of Circadian Misalignment

<table>
<thead>
<tr>
<th></th>
<th>Aligned</th>
<th>Misaligned</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Actigraphy Sleep Duration (h)</strong></td>
<td>6.4 (1.2)</td>
<td>5.5 (1.4)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td><strong>Latency (m)</strong></td>
<td>10.4 (15.1)</td>
<td>13.0 (24.9)</td>
<td>0.29</td>
</tr>
<tr>
<td><strong>Number of Awakenings</strong></td>
<td>1.7 (1.9)</td>
<td>1.8 (1.8)</td>
<td>0.36</td>
</tr>
<tr>
<td><strong>Sleep Efficiency</strong></td>
<td>89% (7%)</td>
<td>90% (7%)</td>
<td>0.18</td>
</tr>
<tr>
<td><strong>Sleep Quality</strong></td>
<td>66.8 (17.7)</td>
<td>60.2 (21.0)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td><strong>Alertness</strong></td>
<td>57.9 (21.7)</td>
<td>53.5 (21.4)</td>
<td>0.14</td>
</tr>
</tbody>
</table>

Flynn-Evans *et al.*, *In preparation*, 2014
Circadian Phase Shift by Day of Simulation

Flynn-Evans et al., In preparation, 2014
Performance Results

Flynn-Evans et al., *In preparation*, 2014
Short-Haul Airline Operations
Early Starts/Irregular Schedules

• Early morning starts are a circadian challenge
  • Circadian wake maintenance zone prevents early bedtime

• Irregular schedules prevent regular bed- and wake times

• Lead to chronic and acute sleep debt and circadian misalignment
Study Methods

• Systematic evaluation of schedule types
  • Baseline, early, evening, night schedules
  • Assessment during duty days and days off

• Outcomes
  • Hassle factors
  • PVT on iPod
  • Actigraphy
  • Sleep logs
  • Sleepiness scales, countermeasure logs
  • Urine collection for melatonin assessment

• Data Mining
  • Operational outcomes
  • Correlations with fatigue measures

n = 44 study
n = 13 urine collection
Bedtime and Wake Time by Schedule Type

Flynn-Evans et al., In preparation, 2014
Circadian Phase Shifts by Schedule Type

Melatonin Acrophase by Individual

Flynn-Evans et al., In preparation, 2014
Sleep Duration Shorter on Early and Late Shifts

Flynn-Evans et al., *In preparation*, 2014
Countermeasures Used During Flight

Flynn-Evans et al., In preparation, 2014
Key Practical Take Away Points

• Sleep loss remains a concern in spaceflight and aviation

• Circadian misalignment accounts for substantial sleep loss in many high stress environments

• Scheduling and light countermeasures available to facilitate increased sleep duration and performance enhancement

• Fatigue Risk Management Systems must provide better education about circadian misalignment and how to prepare operators for non-traditional shifts