Sleep and Workload in Shuttle Missions: Implications for Current and Future Spaceflight

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Alexandra Whitmire, PhD
Lauren Leveton, PhD
Kelley Slack, PhD
James Locke, MD
Outline

• Behavioral Health and Performance Research Element
• Sleep Quality Questionnaire (SQQ) – Shuttle Flyers
  • Background
  • Objectives
  • Methods
  • Highlight - Results
• Fatigue Management in Current Operations
• Future Mission Recommendations
BHP Requirements

• Characterize and assess risks (e.g., likelihood and consequences)
• Develop tools and technologies to prevent, monitor, and treat adverse outcomes
  • Human systems integration & minimize resources
• Inform standards
Sleep Quality Questionnaire - Overview

• In 2008, BHP approached by Flight Surgeon Dr. James Locke regarding sleep, workload and fatigue issues on orbit
  • Anecdotal reports since Apollo missions
  • Research indicating reduced sleep in-flight
    • Barger & Czeisler et al., preliminary data
    • Djik et al., 2001
    • Monk et al., 1998
    • Gundel et al., 1997
    • Santy et al., 1988
Numerous ground studies demonstrate sleep in these quantities for 7 consecutive nights leads to lapses of attention equivalent to those seen after one night of total sleep deprivation; after 11 nights of reduced sleep (4-6 hours “time in bed”) severe impairment (i.e., memory affects, increased errors, injuries) manifests (Van Dongen et al., 2003).

Additional long-term deleterious outcomes are associated with sleep loss and circadian desynchronization include:

- Glucose intolerance, diabetes, and metabolic disorders
- Mood disorders, depression, and anxiety
- Cardiovascular disease
- Immune suppression

Organizational impact: Estimates of lost productivity due to poor sleep cost $3,156 per employee per year with insomnia, and averaged about $2,500 for those with less severe sleep problems. Across 4 companies (~4000 employees) assessed, sleep-related reductions in productivity cost $54 mil/yr (Rosekind et al., 2010).
**SQQ- Method**

- In conjunction with Dr. Locke and sleep expert Dr. David Dinges, we developed an on-line survey and a questionnaire for one-on-one interviews. Three astronauts reviewed the items for face validity.

- Astronauts who have flown Shuttle Missions (starting with the single 2005 mission, STS-114, through astronauts returning from STS-130, in February 2010) were recruited for the study. Interviews ended in Summer of 2010.

- A total of 66 flyers completed the survey and follow-up interview; an additional 10 astronauts completed just the interview.
  - Participants were sent a link to a secure on-line survey, which they completed at their leisure. Surveys took approximately 20 minutes to complete.
  - Follow-up interviews were conducted one on-one with trained representatives from NASA Space Medicine and Behavioral Health and Performance. These interviews took between 45 minutes to one hour.

- Limitations: Retrospective, Subjective
Survey Analysis

Potential Predictors:
1) Falling asleep on Earth
2) Staying asleep on Earth
3) Sleep medication use on Earth
4) Sleep medication use in space
5) Preflight preparation
6) Preparing with crewmates
7) Commander restrictions
8) Thinking as sleep hindrance in space
9) Fatigue effects
10) Physical comfort
11) Scheduled workload
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Falling Asleep in Space v. Earth

Falling asleep in space and falling asleep on Earth. 78% of participants agreed that it is easy to fall asleep on Earth (versus 54% in space), while 14% disagreed (versus 35%). Ease of falling asleep on Earth did not predict ease of falling asleep in space ($r = .02$, not significant).

Astronauts who find it difficult to fall asleep on Earth are less likely to fall asleep easily in space ($r = .27, p = .03$). However, the fact that astronauts fall asleep easily on Earth does not mean that they will do so in the spaceflight environment. Most crewmembers reported experiencing more difficulty with falling asleep in space than with falling asleep on Earth.
### Falling Asleep in Space

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<th>Mission</th>
<th>Shuttle Environment</th>
<th>Crew</th>
<th>Individual</th>
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<tbody>
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<td>• Commander policies</td>
<td>• Use of sleep medications *</td>
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*Factors that were significantly associated with the outcome “falling asleep in space.”*
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Interview Analysis

Transcribed the interview recordings, yielding over 4000 lines of data.

The purpose of the interview data analysis was to conduct frequency counts and identify whether there were recurring ‘themes’ that emerged in response to questions.

Responses were then separately coded within each of the questions by counting the number of times a reply was given.

Several categories of responses emerged that were consistent with most of the statistically significant factors as seen in the survey.
What Kept You From Falling Asleep in Space

- Thinking / Active Mind: 24%
- Workload / Lack of Wind down: 10%
- Unfamiliar Environment: 10%
- Physical Discomfort: 9%
- Don't Know: 4%
- Environment - Light: 4%
- Sleep Medications Helped with Falling...: 17%
- Non Issue: 20%

Percentage of participants who discussed the indicated factors when asked what kept them from falling asleep in space. Based on a total of 107 responses (n = 70). Participants could provide more than one response.
“I’m sure my stress level increased as the mission went along just because you’re getting more and more fatigued, so I think I’m more easily stressed. That may have contributed to a greater difficulty sleeping more hours during the night later in the mission.”

“I think for the folks who didn’t get a lot of sleep, it was probably the anxiety over the workload more than the complexity of the task that was driving it. All the sleep loss on our [mission] was stress related.”

“My brain wandering [inhibited sleep]. Once you’re there for a couple of days, and you do your normal routine, and you realize ‘I’m trained for all this stuff and none of it is really stuff I’ve never seen before,’ other than habitability kind of things. That’s the stuff you haven’t seen before, but once you do a day or two of pre- and post-sleeps, and you figure out your routine, it’s then that it’s okay.”
Ease of falling asleep in space and use of sleep medicine. Ball indicates the number of astronauts endorsing the option. The cluster of dark blue balls illustrates that those who fall asleep easily in space did not use sleep medicines whereas those who had difficulty falling asleep in space did use medicine as a sleep aid.
# Positive and Negative Attributes

<table>
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<th>Drug</th>
<th>Positive Attributes</th>
<th>Negative Attributes</th>
<th>+/− Ratio</th>
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<tr>
<td>Ambien</td>
<td>a, b</td>
<td>A, B, C, D, E, F, G</td>
<td>0.85</td>
</tr>
<tr>
<td>Sonata</td>
<td>a, b, c, d</td>
<td>A, C, E, F, J</td>
<td>1.80</td>
</tr>
<tr>
<td>Ambien CR</td>
<td>a, f, g</td>
<td>C, D, E, F</td>
<td>0.75</td>
</tr>
<tr>
<td>Phenergan</td>
<td>b</td>
<td>A, E</td>
<td>0.50</td>
</tr>
<tr>
<td>Restoril</td>
<td>no positive effects reported</td>
<td>A, B, C, E, F</td>
<td>0.00</td>
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**Legend:**
- Length indicates the number of astronauts who took the drug.
- Positive Attributes:
  - a: No side effects
  - b: Effective
  - c: Not groggy in the morning
  - d: Short acting
  - e: Not addicting
  - f: Lasted through the night
  - g: Of all medications, works the best
- Negative Attributes:
  - A: General side effect
  - B: Specific side effect
  - C: Ineffective
  - D: Negative effects after prolonged use
  - E: Groggy in the morning
  - F: Too short acting
  - G: Delayed onset
  - H: Too strong/heavy
  - I: Different between Earth and space
  - J: Used, but prefer to avoid
My main problem on my first flight was that the more I worried about getting enough sleep, the less I slept... [During this recent flight] I took an alertness medication before EVA. I didn’t see any adverse effects at all from it [and knowing it was available] probably gave me the ability to get an extra hour of sleep each night because I wasn’t worried about stuff anymore."

"I think it’s fair when I say I observe that [people use the stimulants] and I was a little bit worried about it. The use of stimulants is done quite a bit. I do not understand why though."

"I think it’s different for everybody. Everybody’s body reacts differently. I just wanted to have it available if I thought I might need an alertness medication and that’s the way I would do it. Just be prepared but don’t count on it."
Mitigation Strategies

- Stress management training
- Education and individualized training related to medications, including alertness medications
- Control of light leakage in sleep areas
- Pre-testing and individual selection of eye covers and ear plugs
- Protected pre-sleep wind-down time
- Increased self-awareness of own fatigue and teammate fatigue
- Closely working with other crewmembers to “back up” one another on tasks
- Working through tasks more slowly and methodically
- Adhering to processes (i.e. checklists) to prevent fatigue-related errors
The CPG outlines a tiered approach for CM

**Tier 1**
- Scheduling
- Education and Training
- Environment

**Tier 2**
- Light
- Non-Prescription Chronobiologic, Sleep and Alertness Substances

**Tier 3**
- Cognitive Behavioral Therapy
- Pharmacologic* Interventions
  - Chronobiologic Medications
  - Hypnotic Medications
  - Alertness Medications

The CPG further outlines steps for a crew surgeon to follow in providing clinical care.
Light as a Countermeasure

Replacement Lights ISS

Brightness: 420 lux
Color: 6500K + emphasize blue
deemphasize red

Brightness: 210 lux
Color: 4100K full spectrum

Brightness: 65 lux
Color: 2700K deemphasize blue
ephasize red
Future Missions

- Unobtrusive objective measures of sleep
- Unobtrusive, sensitive performance measures
- Individualized mathematical models that predict performance (based on sleep – wake history) and integrate countermeasures such as medications
- Research on behavioral makers for future selection recommendations and countermeasure regimens
- Education and training programs
- Individualized lighting protocols
- Habitat recommendations for future vehicles – volume and layout
- Individualized protocols for alertness and hypnotic medications
Thank you!

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