FATIGUE IN U.S. ASTRONAUTS ONBOARD THE INTERNATIONAL SPACE STATION: ENVIRONMENTAL FACTORS, OPERATIONAL IMPACTS, AND IMPLEMENTATION OF COUNTERMEASURES

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Background

- Crewmembers have experienced fatigue for reasons similar to military deployments. Astronauts experience psychological stressors such as
  - heavy workloads
  - extended duty periods
  - circadian misalignment
  - inadequate/ineffective sleep
  - distracting background noise
  - unexpected and variable mission schedules
  - unfavorable thermal control
  - unusual sleep environment with schedules that impinge on pre-sleep periods

Factors related to spaceflight

- Physiological contributors to poor sleep and fatigue unique to microgravity include a cephalad fluid shift, elevated CO_2 levels, space motion sickness, elevated intracranial pressure, loss of neurovestibular function, and back pain

Sleep hygiene impaired by the novel spaceflight environment

- Restful sleep is further challenged due to a lack of gravity-related proprioceptive cues and need for restraints

Etiology of chronic fatigue in space

- Interestingly, the chronic fatigue astronauts report early on in their 6-month mission may be secondary to transitioning from a planar environment to a 360° microgravity perspective

Operational impacts of chronic fatigue in space

- The term “space fog” has been used by astronauts to describe a phenomenon of
  - Forgetfulness
  - slowed reaction time
  - transient confusion while trying to complete tasks
- Space Fog is not a loss of cognitive ability
  - It is a loss of the usual environmental stimuli that reinforce memory

Alterations in sleep and resultant performance decrements in spaceflight

Long Hours of Wakefulness Degrades Performance

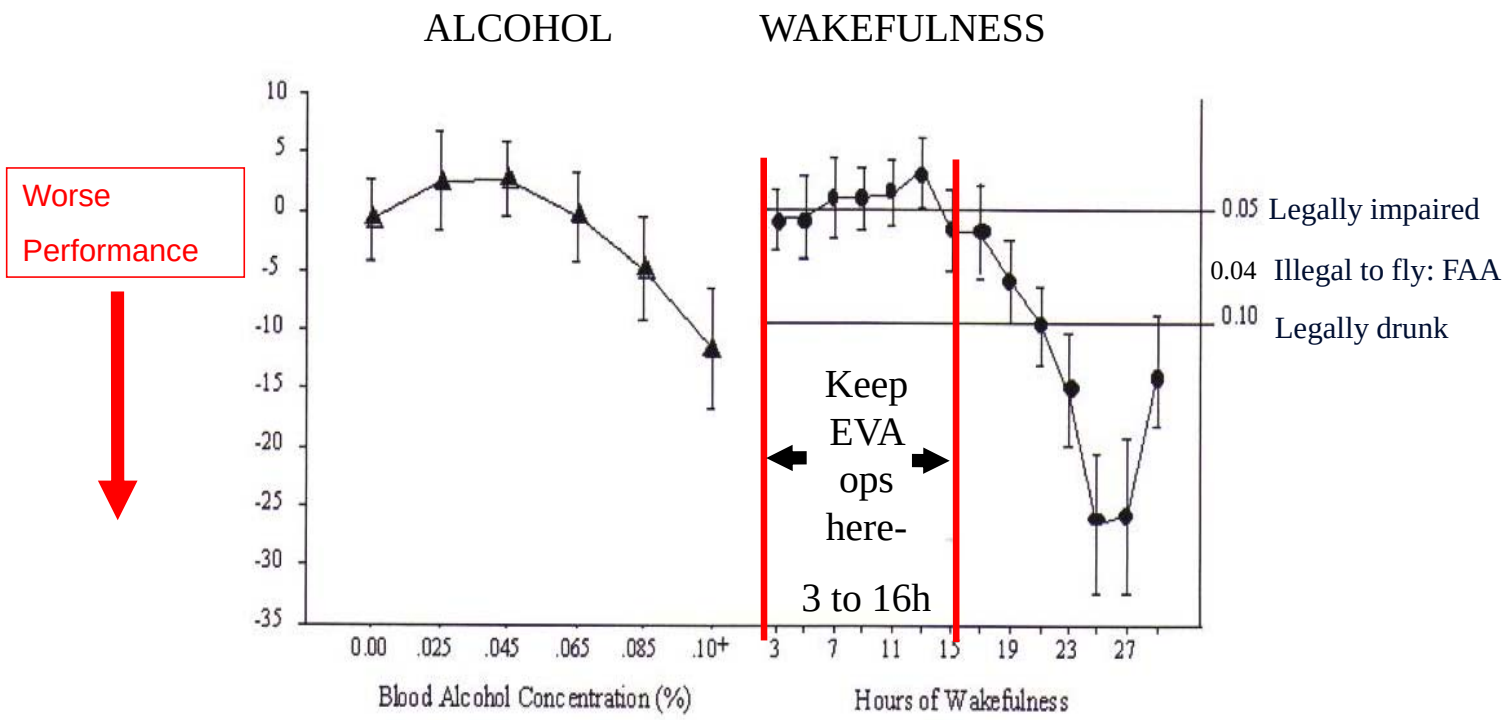


FIG. 1. Mean relative performance levels for the response latency component of the grammatical reasoning task in the alcohol intoxication (left) and sustained wakefulness condition. The equivalent performance decrement at a BAC of 0.05% and 0.10% are indicated on the right hand axis. Error bars indicate ± one s.e.m.

Dawson, D. and Reid, K. Fatigue, alcohol and performance impairment. Nature, 388: 235, 1997

Example

The New York Times

Astronaut Error Adds New Anxiety on Space Station

July 18, 1997

By MICHAEL R. GORDON

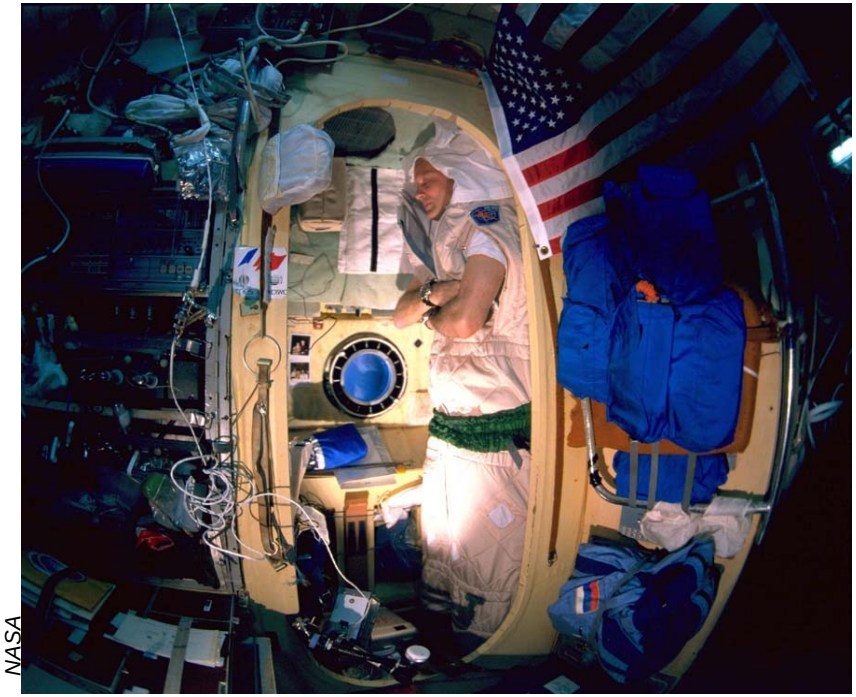
MOSCOW -- An astronaut aboard the Mir mistakenly disconnected a critical cable on Thursday, disabling the guidance system that enables the space station to gather solar energy and causing yet another crisis for the trouble-plagued craft...

The repair mission will also be delayed because the crew has been instructed to take several days off and get more rest. That is an implicit recognition that fatigue is believed to have played a role in the mistake on Thursday. The Russian crew members were reported to have had a sleepless night.

"This was purely human error." [Mission Director Vladimir] Solovyov said.

Countermeasures

- Judicious use of stimulants and hypnotics, light therapy, controlled sleep periods, sleep shifting for visiting vehicle operations or EVA, and reducing ambient CO2 levels are a few of the most promising countermeasures being used in space to improve sleep and reduce fatigue.



NASA

Light as a countermeasure

Circadian "Daily Biological" Rhythm

- Internal clock regulates a **circadian rhythm** of 24.2 hrs a day (Czeisler et al., 1999)
- **Light** serves as the strongest external stimulus for maintaining circadian alignment to Earth's 24-hour day/night cycle

Brightness

- Evidence clearly shows that bright light hastens schedule shifting, improves circadian entrainment, increases alertness and performance
- Perceived brightness of a light depends on its color and surrounding conditions

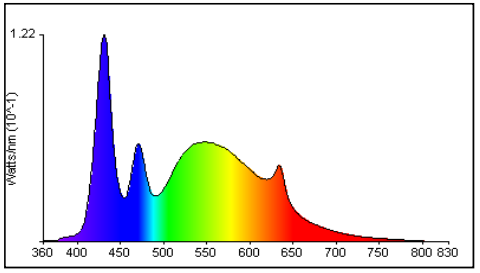
Wavelengths

Specific wavelengths optimize light as a countermeasure

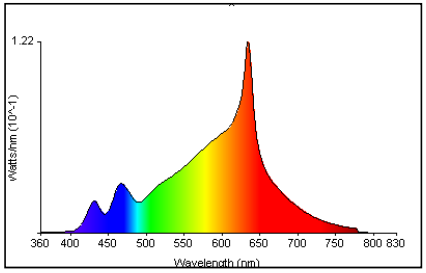
- Blue wavelengths (440nm-550nm) hasten schedule shifting and increases alertness
- Red wavelengths (620nm-730nm) enable pre-sleep by not stimulating alertness
- Optimizing the wavelength of light permits reducing the brightness and electrical power utilization, while still achieving an effective lighting countermeasure (Brainard et al., 2001, 2010; Lockley et al., 2003, 2006)

Countermeasures

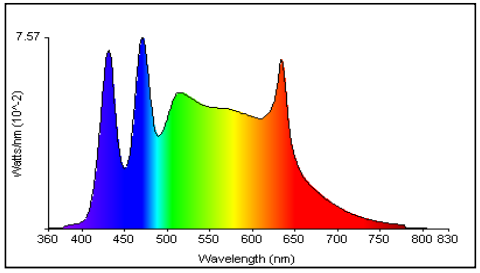
Replacement Lights ISS



Brightness: 1500 lux
Color: 6500K + emphasize blue deemphasize red



Brightness: 50-100 lux
Color: 2700K deemphasize blue emphasize red



Brightness: 300-500 lux
Color: 4100K full spectrum

Countermeasures *cont'd…*

- These countermeasures to improve sleep duration and quality in astronauts on the ISS have been instituted with moderate degrees of success as measured by self-reaction time (psychomotor vigilance task testing), actigraphy, and subjective reports.