Lighting Effects

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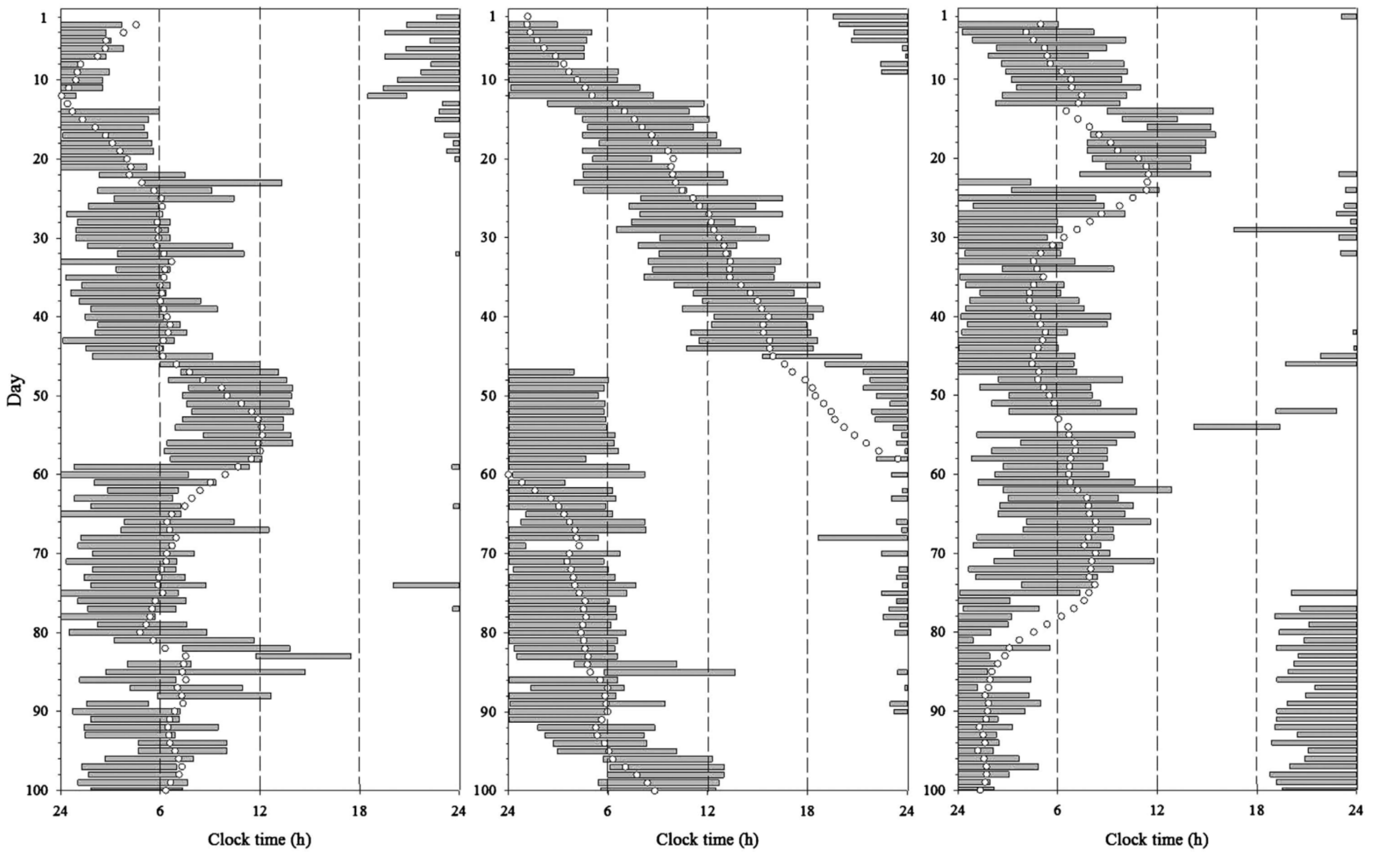
Science Background

Circadian clock misalignment is common during long duration spaceflight



EE Flynn-Evans et al., npj Microgravity, 2016

Science Background

Sleep disruption is common during long duration spaceflight

Table 3. Sleep characteristics during nights in flight where the temperature minimum was predicted to occur during the sleep episode compared with nights predicted to occur outside the sleep episode

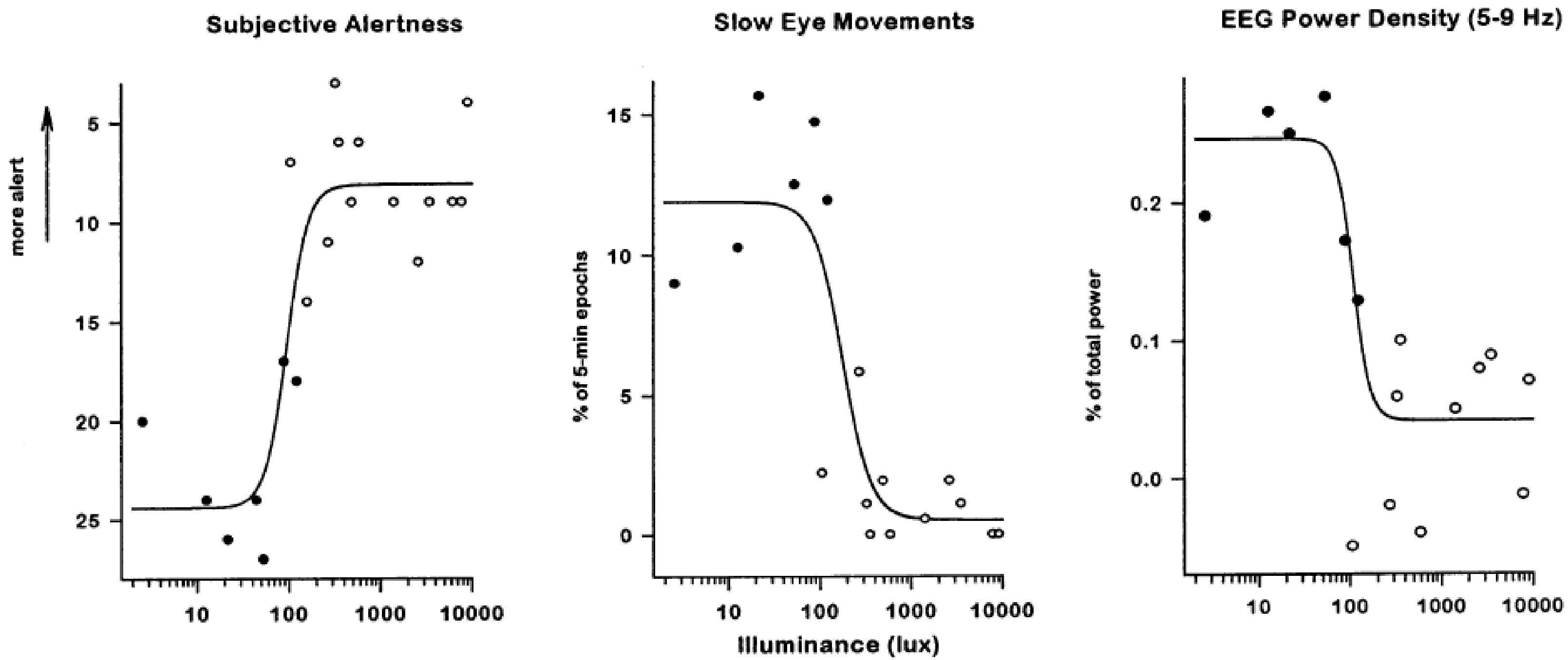
	Aligned	*Misaligned*	
	Mean (s.d.)	*Mean (s.d.)*	P-value
Actigraphy sleep duration (h)	6.4 (1.2)	5.4 (1.4)	< 0.0001
Latency (m)[a]	10.3 (15.0)	13.2 (25.2)	0.26
Number of awakenings[a]	1.7 (1.9)	1.7 (1.7)	0.38
Actigraphy sleep efficiency	89% (7%)	90% (7%)	0.26
Sleep quality[a]	66.8 (17.7)	60.2 (21.1)	0.01
Alertness[a]	57.9 (21.7)	53.6 (21.5)	0.13

[a]Self-reported from sleep diary reports.

EE Flynn-Evans et al., npj Microgravity, 2016

Science Background

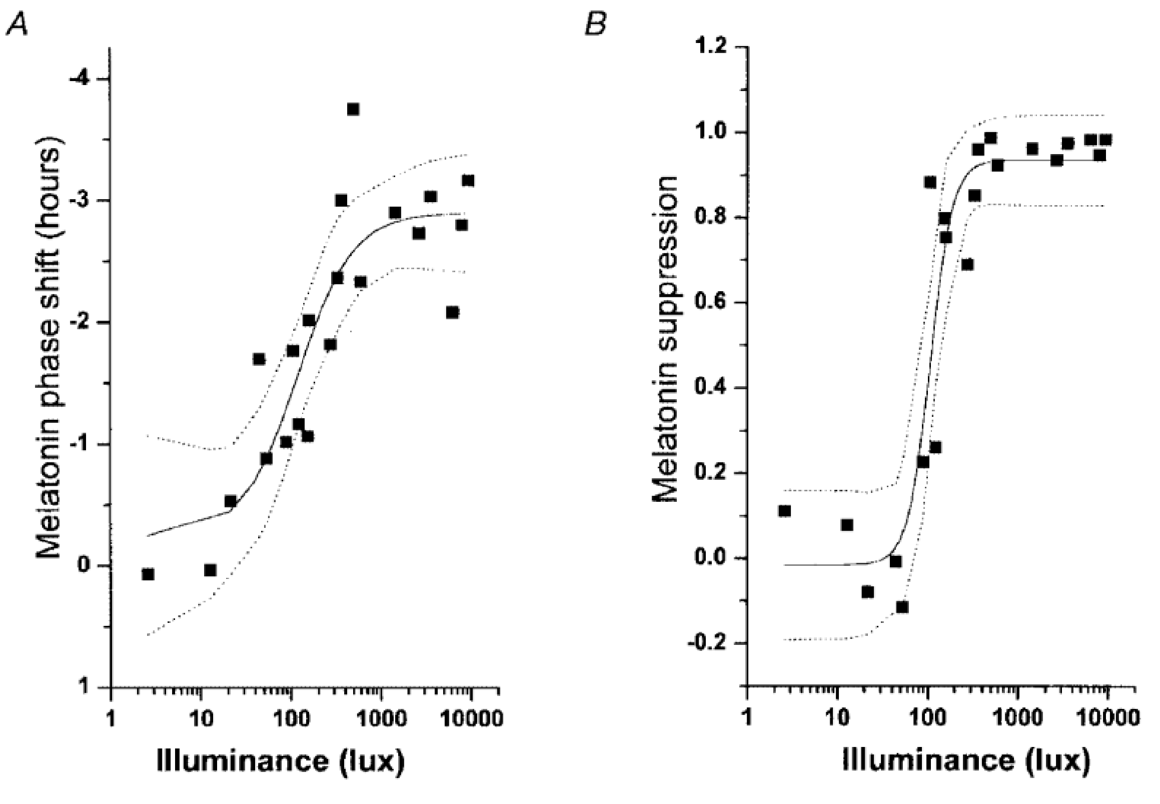
Light is a stimulant



Cajochen et al., Behav Brain Res, 2000

Science Background

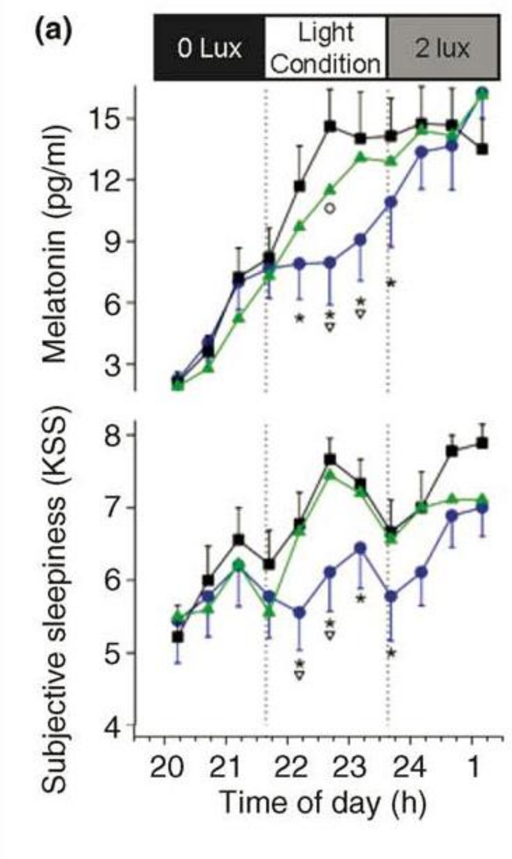
Light shifts the circadian clock

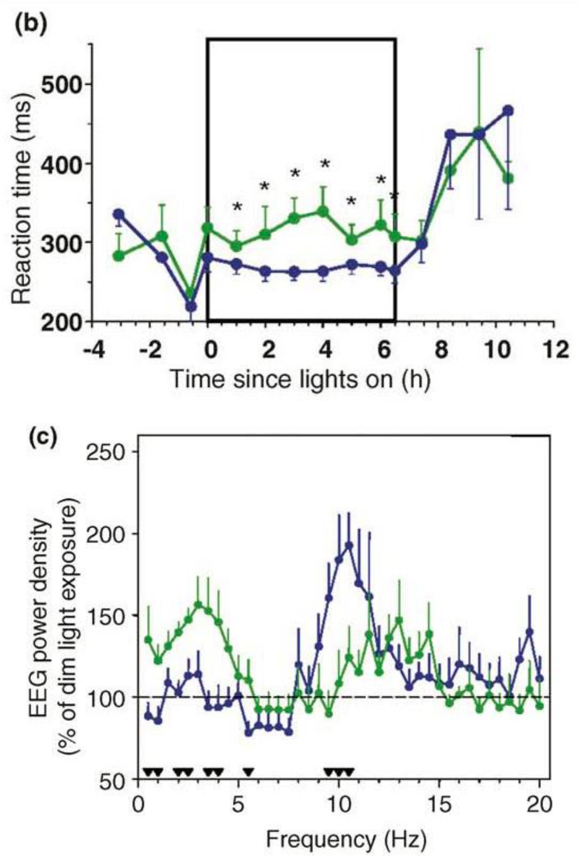


Zeitzer et al., J Physiol, 2000

Science Background

Effect of light exposures on melatonin secretion, subjective sleepiness, performance





Cajochen et al., J Clin Endocrinol Metab, 2005 **Lockley et al., Sleep, 2006**

Science Background

- **Countermeasures can reduce** the risk of errors, accidents or injuries due to sleepiness

- **Light as a stimulant represents** a non-pharmaceutical, safe, and reversible countermeasure to reduce sleepiness or, when removed, can promote sleep

- **Light helps reset circadian rhythms** after a sleep-wake cycle shift and maintain circadian entrainment

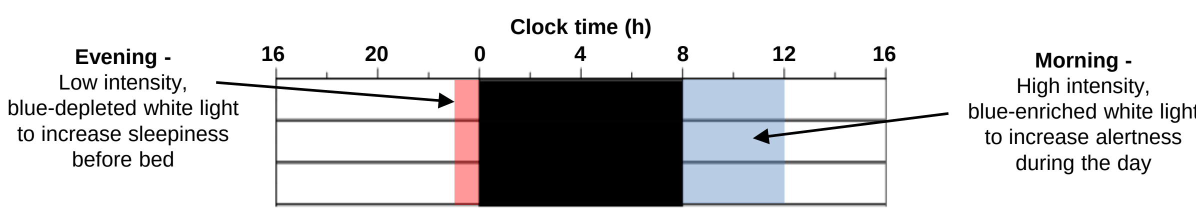
Project Background

New LED lighting will be installed on the ISS to replace the current fluorescent General Luminaire Assemblies (first installation planned late 2016)

New Solid State Lighting Assemblies (SSLA) have multiple LEDs and can produce **white light** of varying intensities and spectra

We have designed a Dynamic Lighting Schedule that has 3 pre-set light settings and guidelines for how to use in various scenarios:

1) **High Visual Acuity**: Standard white light (4500K, 210 lux) for normal tasks
2) **High Circadian Shifting / High Alertness**: Blue-enriched white light 6500K, 420 lux) following sleep or shift
3) **Low Circadian Shifting / Low Alertness, Pre-sleep**: Blue-depleted white light (2700K, ≤50 lux) for use before sleep



Study Objective

To test the efficacy of lighting protocols for daily operations using SSLAs for in-flight crewmembers onboard ISS missions.

We will assess the acceptability, use and operational impact of deployment of the Dynamic Lighting Schedule protocol on astronaut vision, sleep, alertness, circadian rhythms and general well-being during flight missions aboard the ISS.

Study Hypotheses

We will test the hypotheses that compared to current static, fluorescent General Illumination only, the Dynamic Lighting Schedule protocol will:

a) maintain acceptable visual performance and color discrimination for operational tasks
b) improve stability of circadian entrainment
c) improve circadian adaptation following a sleep shift (e.g. slam-shift)
d) improve sleep duration and efficiency
e) enhance wake-time alertness and cognitive performance

Study Overview

We will compare data from crewmembers working under new SSLA lighting with historic data collected during past missions under the current lighting (n=6 per group).

Measurement approach

Experiment Design Overview

Preflight	Inflight	Postflight
48-Hour Urine Collection 2x – L-180 & L-45**	24-Hour Urine Collection 2x – during normal schedule and following a sleep shift**	48-Hour Urine Collection 1x – R+30**
Actigraphy & Daily Sleep Log (2-week session) 2x – L-180 & L-45	Actigraphy & Daily Sleep Log (2-week session) 2x - during normal schedule and encompassing a sleep shift	Actigraphy & Daily Sleep Log (2-week session) w / Debrief 1x – R+30
Cognition (3/day) 2x – L-180 & L-45	Cognition (3/day) 2x - during normal schedule and following a sleep shift**	Cognition (3/day) 1x – R+30
Visual Performance Tests 1x – L-180 or L-45	Visual Performance Tests 5x	Visual Performance Tests 1x – R+14 (R+21-30 if not returning directly to US)
	Light Meter Operations 7x	

** Note: If crewmembers are collecting urines as part of the BIOCHEMICAL PROFILE study, urine samples may not be required – the samples will be shared whenever possible.

Expected results

- **Aim 1:** Outcome measures from the NVT and FM-15 to assess visual performance and acuity. **Compared to existing GLAs, SSLA settings will maintain acceptable visual performance and color discrimination for operational tasks.**

- **Aim 2:** Urinary 6-sulphatoxymelatonin (aMT6s), and cortisol to assess circadian phase and period. **Compared to existing GLAs, SSLAs will improve stability of circadian entrainment and circadian adaptation following a sleep shift (e.g. slam-shift).**

- **Aim 3:** Sleep latency, sleep efficiency, number of awakenings after sleep onset, and total time awake after sleep onset will be calculated from the diaries. **Compared to existing GLAs, SSLAs will improve sleep duration and efficiency.**

- **Aim 4:** The performance test battery to assess reaction time, psychomotor vigilance, working memory, and decision-making. **Compared to existing GLAs, SSLAs will enhance wake-time alertness and cognitive performance.**

Significance and benefits

- This project will generate quantitative data on:
  - crew health
  - habitability
  - environment
  - human factors

  These data will facilitate in the design of future human space flight vehicles and habitats.

- The project also will provide guidance for flight surgeons, flight psychologists, and astronauts to help optimize sleep and circadian regulation during space exploration missions.

- Moreover, these data can help design lighting countermeasures for anyone working night, rotation, or extended wake schedules (e.g., medical, security, and transportation personnel), and traveling across multiple time zones.