Understanding Sleep Regulatory Processes to Improve Waking Performance

1st :envihab Symposium
Cologne, Germany
May 23, 2011

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Around-the-Clock Operations, Performance and Sleep

• ~15% of the work force in modern societies work rotating shifts or night shifts

• Relation between homeostatic and circadian process is altered during shift work

• Altered relationship ⇒ Performance ↓, Sleep ↓

• Can sleep researchers offer countermeasures?
Daytime work:
Sleep pressure opposed by circadian wake drive
⇒ Adequate performance

* Sleep pressure: derived from Two-process model
  Circadian wake drive: % awake derived from forced desynchrony protocol
Night work:
Sleep pressure↑ + Circadian wake drive↓
⇒ Poor performance

* Sleep pressure: derived from Two-process model
Circadian wake drive: % awake derived from forced desynchrony protocol
Testing Two Experimental Countermeasures to Improve Performance during Simulated Night Work Protocol

Evening sleep + phase advancing light (N=17)

Clock Time (h)

Morning sleep + phase delaying light (N=17)

Santhi et al., J Biol Rhythms, 2008
Light induced phase advance in the *Evening* sleep group

Light induced phase delay in the *Morning* sleep group

Santhi et al., *J Biol Rhythms*, 2008
Evening Sleep with Phase Advancing Light is Effective Countermeasure for Attentional Impairment during Night Work

Santhi et al., J Biol Rhythms, 2008
Relationship between Homeostatic Sleep Pressure, Circadian Wake Drive, and Melatonin Secretion

Adapted from Dijk et al, J Physiol 1997
Nighttime Sleep (Entrained)

Sleep Pressure

Circadian Wake Drive

⇒ Consolidated Sleep

Daytime Sleep

Sleep Pressure

Circadian Wake Drive

Exogenous Melatonin?

⇒ Premature Awakenings
Plasma Melatonin Profile after Oral Melatonin Administration

- Fast rise
- Short half-life
- High dose needed

Wyatt et al, Sleep 2006
Protocol to Test Efficacy of Skin Patch to Deliver Melatonin during Daytime sleep

(N=9)

Aeschbach et al, Clin Pharmacol Ther 2009
Transdermal Melatonin Delivery (2.1 mg) is Effective in Increasing Plasma Melatonin Levels for Extended Time

(N=9)
Randomized, Crossover
Double-blind

Aeschbach et al, Clin Pharmacol Ther 2009
Transdermal Melatonin Improves Sleep Maintenance by Increasing Sleep Efficiency in the Latter Part of a Daytime Sleep Opportunity

Aeschbach et al, Clin Pharmacol Ther 2009
Conclusions

Scheduling sleep in the evening together with phase advancing light exposure can
- lower homeostatic sleep pressure
- induce circadian realignment
- reduce attentional impairment at nighttime

Transdermal melatonin delivery
- can improve sleep maintenance during daytime
- holds promise as a sleep aid for night workers
Acknowledgments

Nayantara Santhi, PhD
Charles A. Czeisler, PhD, MD
Brandon J. Lockyer, RPSGT
Todd S. Horowitz, PhD
Steven W. Lockley, PhD
Derk-Jan Dijk, PhD
Eli S. Nuwayser, PhD
Larry D Nichols, PhD

Grants:
NHLBI (R01 HL52992, R01-HL077399)
NINDS (R44-NS43129)
Effect of Melatonin on NREMS EEG Spectra:

- Delta/Theta Activity ↓
- Activity in Spindle Frequency Range ↑

Last 6 h of Time in Bed as % of first 2 h
No Adverse Effect of Increased Plasma Melatonin Following Transdermal Delivery during Daytime
Evening Sleep with Phase Advancing Light is Effective Countermeasure For Attentional Impairment during Night Shift

Attentional Impairment (number of long response times in PVT)

Subjective sleepiness (KSS)

Santhi, J Biol Rhythms, 2008
Evening Sleep with Phase Advancing Light is Effective Countermeasure for Attentional Impairment during Night Shift

**Evening Sleep**

![Graph showing response times](image1)

**Morning Sleep**

![Graph showing comparison between evening and morning sleep](image2)

Attentional Impairment (number of long response times in PVT)

Santhi, J Biol Rhythms, 2008
Effect of Dermal Melatonin on Last Third of Daytime Sleep (i.e. when plasma melatonin is highest)

REM Stage 2

Melatonin

Placebo

Minutes

* p<0.05