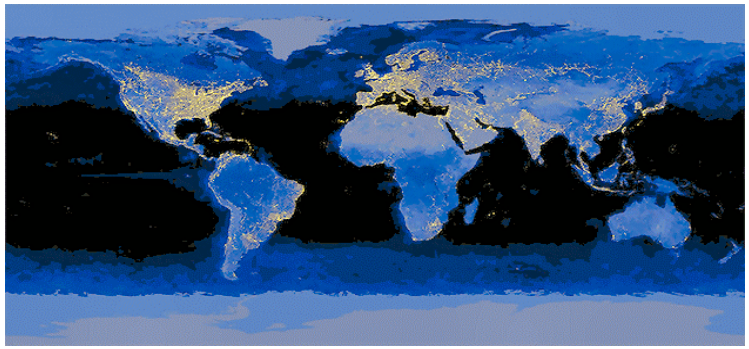
Managing Sleep to Sustain Performance

Gregory Belenky, M.D.
Sleep and Performance Research Center

Sustaining Operational Effectiveness

The Earth at Night: The Problem of 24/7 Operations



The Operational Environment Defined

- *Operational Environment*
  - *Human performance critical to correct outcome of the system – the outcome itself is critical*
  - *There a temporal envelope within which the correct decision must be made or the system fails*
  - *John Boyd and the Observation, Orientation, Decision, Action (OODA) Loop*
- *Many operational settings involve 24x7 operations, extended work hours and shift work*

Examples of the Operational Environment

- *Transportation (air, truck, rail, sea, space)*
- *Manufacturing*
- *Military*
- *Mining*
- *Medicine*
- *Finance*
- *First responders (police, fire, etc.)*

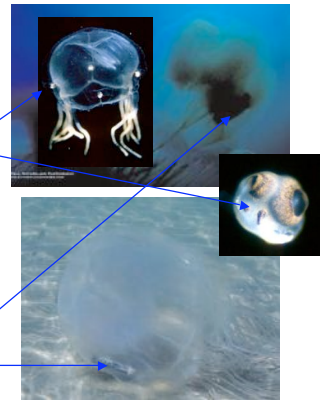
Sleep and Performance

Sleep:
A Fundamental Mystery in Neurobiology

- *We do not know:*
  - *Why extended waking degrades performance?*
  - *How sleep restores performance?*
- *We do know:*
  - *Adequate sleep sustains performance*
  - *Inadequate sleep degrades performance*
- *Sleep is found humans, mammals, birds, reptiles, fish, insects, even (perhaps) jellyfish – any animal with assemblies of nerve cells (neuronal assemblies)*
- *Sleep, like politics, appears to be local to neuronal assemblies*

Sleep in the Box Jellyfish (Chironex fleckeri)

- *Box jellyfish are one of the simplest multi-cellular organisms*
  - *A nervous system consisting of a few neuronal assemblies*
  - *No brain per se, as symmetry is radial rather than bilateral*
  - *Their visual system is complex*
- *Box jellyfish are quiescent 15 hours/day*
  - *Diurnal pattern*
  - *Active during the day (0600-1500 hours)*
    - *Move 212 m/hour during day*
    - *Move 10 m/hour at night*
- *Note attached movement/location sensors*



Seymour et al., 2004

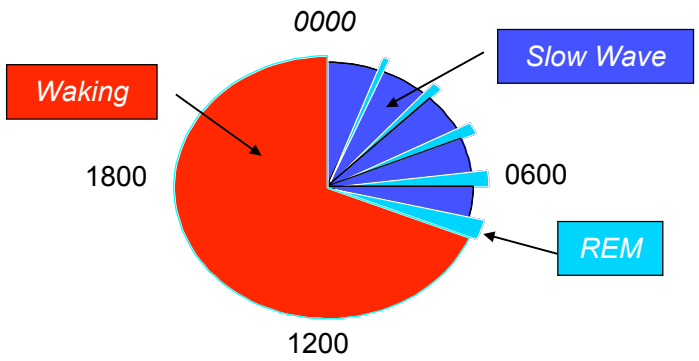
Sleep and Other Factors Affecting Performance

- Time awake (sleep/wake history)
- Time of day (circadian rhythm)
- Time on task (~shift length; % of shift spent on task)
- Sleep inertia
- Individual differences in response to
  - Time awake
  - Time of day
  - Time on task
  - Sleep inertia
- Adaptation to restricted sleep

Consequences of Sleep Restriction and Sleep Deprivation

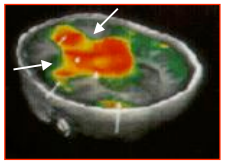
- Short term
  - Minutes, hours
  - Error, accident, catastrophe
- Mid-term
  - Weeks, months, years
  - Bad planning, inadequate strategizing, poor life decisions
- Long-term
  - Years
  - Overweight/obesity, Type II Diabetes, Sleep Disorder Breathing, Metabolic Syndrome, etc.
- All based on short-term, local effects acting over short (minutes), medium (days, weeks, months, years) and long time (years) time horizons

The 24-Hour Sleep/Wake Cycle

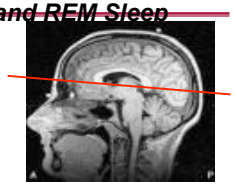


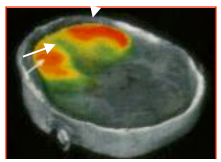
Brain Metabolism during Slow Wave and REM Sleep

Frontal areas are deactivated during Slow Wave Sleep; decline in flow of ~30%



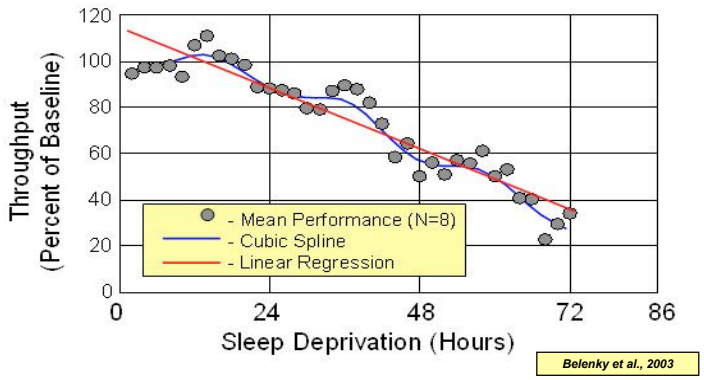
Frontal areas remain deactivated during REM; increase in flow to waking levels or above except in prefrontal cortex





Frontal areas are re-activated only after awakening

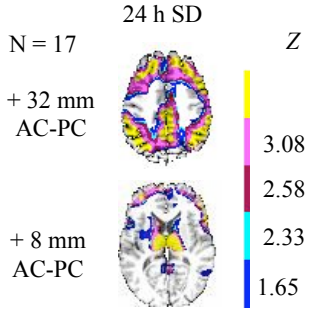
Total Sleep Deprivation and the Circadian Rhythm



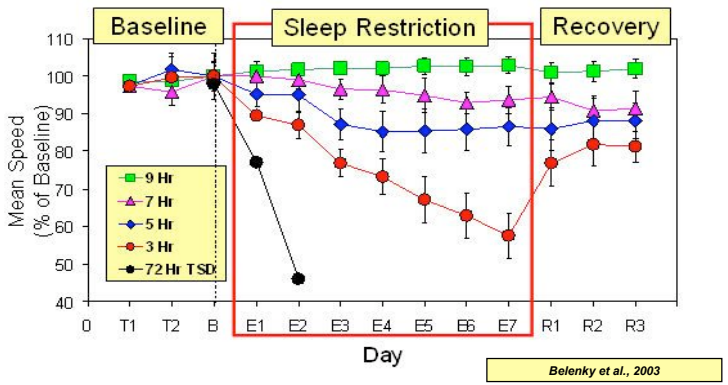
Belenky et al., 2003

Glucose Uptake decreases in Sleep Deprivation: PET ^{18}Flourine 2-deoxyglucose Study

- *6% global decrease in glucose uptake at 24 hours of total sleep deprivation*
- *12-14% decrease in glucose uptake in prefrontal cortex, parietal association cortex, and thalamus at 24 hours of total sleep deprivation*

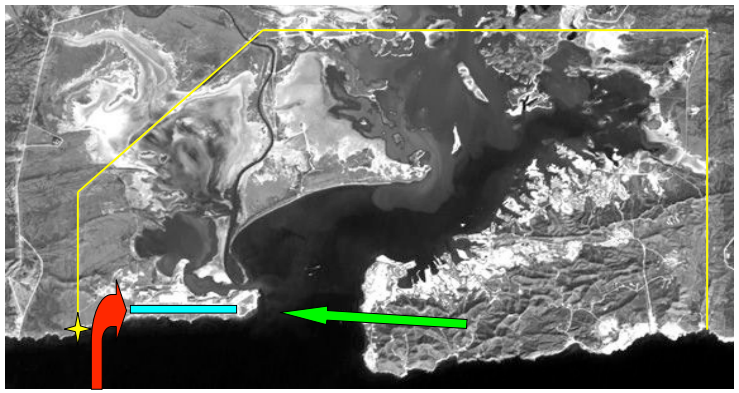


Chronic Sleep Restriction



Belenky et al., 2003

Guantanamo Bay, Cuba



The Approach to Guantanamo

Approach to Guantanamo requires a sharp right bank to avoid Cuban air space

Crash Site

All 3 crew members were rescued from the cockpit and survived

American International Flight 808

18 August 1993

Engineer: Slow, Airspeed
Co-Pilot: Check the turn.
Captain: Where's the strobe?
Co-Pilot: Right over here.
Captain: Where?
Co-Pilot: Right inside there, right inside there.
Engineer: You know, we're not gettin' our airspeed back there.
Captain: Where is the strobe?
Co-Pilot: Right down there.
Captain: I still don't see it.
Engineer: #, we're never goin' to make this.
Captain: Where do you see a strobe light?
Co-Pilot: Right over here.
Captain: Gear, gear down, spoilers armed.
Engineer: Gear down, three green spoilers, flaps, checklist
???: There you go, right there, lookin' good.
Captain: Where's the strobe?
Co-Pilot: Do you think you are going to make this?
Captain: Yeah… if I can catch the strobe light.
Co-Pilot: 500, you're in good shape.
Engineer: Watch the, keep your airspeed up.
Co-Pilot: 140. [sound of stall warning]
???: Don't – stall warning.
Captain: I got it.
Co-Pilot: Stall warning.
Engineer: Stall Warning
Captain: I got it, back off.
???: Max power!
???: There it goes, there it goes!
???: Oh no!

Shiftwork and Shiftwork Sleep Disorder

Shift Workers and Shift-Work Sleep Disorder

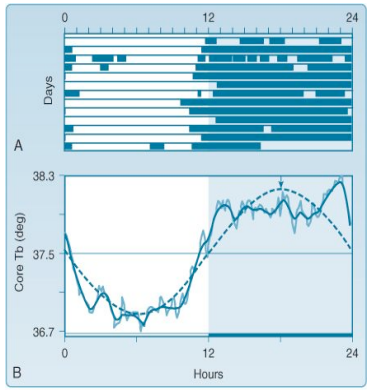
- *~Twenty percent of workers in industrialized countries are shift workers*
  - *Working night shifts*
  - *Working rotating shifts*
- *~Ten percent of shift workers suffer from shift-work sleep disorder, with primary complaints of*
  - *Insomnia and/or*
  - *Excessive sleepiness*
  - *In association with work shifts that occur during the habitual circadian entrained sleep phase*
  - *Shift-lag, similar to jet-lag (trans-meridian desynchronization), except it is chronic*

Shiftwork Sleep Disorder

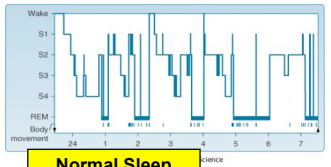
- *Results from interaction of human physiology with environment*
- *People with shift work sleep disorder more at risk for error, incident, accident, illness, or other untoward health consequence*

Circadian Rhythm in Temperature

- *Sleep propensity is the inverse of the circadian rhythm in temperature*
- *As shift workers never synchronize, they are consistently attempting sleep at non-sleep conducive times*

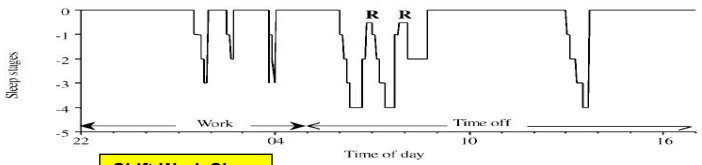


Normal vs. Night Shift-Work Sleep



Normal Sleep

- *Graphs matched on time scale*
- *Note naps during work shift and in late afternoon*
- *Note truncated main daytime sleep*



Shift-Work Sleep

Types of Shifts

- Day
- Afternoon/evening
- Night
- Early morning
- Sleep disruption/truncation greatest for night and morning shifts, least for afternoon/evening
  - Primarily the result of sleeping or awakening at adverse circadian phase
    - Sleeping in the evening
    - Awakening in the early morning

Shift Work Sleep Disorder: Pathophysiology

- Night shift workers sleep/wake cycles are out of phase with circadian rhythms
- The circadian rhythm in temperature is entrained by environmental light
  - When shifting time zones, the light dark cycle shifts as well and one entrains to the new time zone
  - When working night shift and staying in the same time zone, the light dark cycle does not shift and one does not entrain to the new schedule
- Night shift workers are chronically desynchronized
- Sleep propensity a function of time awake and time of day
- Night shift workers are trying to sleep when their circadian rhythm is increasing their alertness and decreasing their sleep propensity

Shift-Work Co-Morbidities

- Night shift workers
  - Slight increase in overall mortality
  - Gastrointestinal disorders more common
  - Cardiovascular disease more common
  - Neoplastic disease more common
  - Diabetes and metabolic syndrome may be more common
- Persons diagnosed with shift work sleep disorder appear more vulnerable than other shift workers to
  - Ulcers
  - Absenteeism
  - Depression

Evening Shift

- Evening shift workers on average sleep more than day shift workers (7.6 vs. 6.8 hours/night) with equal sleep efficiency
- Prevalence of complaint of insomnia or excessive daytime sleepiness (shift work sleep disorder) not different in day and evening shift workers

Rotating Shifts

- Best – fast forward (2 days morning, 2 days evening, 2 days nights
- Worst – slow backward (1 week nights, 1 week evenings, 1 week days)

Other Countermeasures

- Stimulants
  - Caffeine
  - Other stimulant drugs, e.g., modafinil
  - Stimulants (caffeine, d-amphetamine, modafinil) appear equivalent for first few hours in clinically acceptable doses
- Sleep-inducing drugs
- Naps and naps during shift
- Bright Light
- Strict environmental control for sleeping during the day
  - Light and noise while sleeping
  - Commute times to and from work

Fatigue Risk Management Systems (FRMS)

Regulation & Prescriptive Hours of Service Rules

- Currently, rigid, single-line of defense against fatigue related errors, incidents and accidents
  - Hours of service regulations promulgated by regulatory bodies (governmental, international)
  - Context is typically labor management relations
- Assumption – if you live within the regulations you will be safe
  - Ignores local conditions
  - One size fits all approach
  - Likely to be at points overly restrictive and/or unsafe

The Emerging Art and Science of Fatigue Risk Management

- Embed within corporate safety management system (SMS)
  - Move fatigue issues from labor/management to safety
  - Safety enhances productivity (and the reverse)
  - SMS has built-in structure, yields economies of scale
- Fatigue risk management systems (FRMS)
  - Multi-layered defense against fatigue-related error, incident, and accident
  - Each layer "sloppy" but in the Swiss cheese model highly efficient at preventing fatigue-related errors
- Examples are Union Pacific Railroad and Easy Jet Airlines

Union Pacific Railroad Fatigue Risk Management System (FRMS)

- Three-tiered defense-in-depth to prevent fatigue related errors, incidents, and accidents
- Tier 1 – does system of shift timing and duration allow for adequate opportunity for sleep?
  - Computer-based rostering
- Tier 2 – do employees take advantage of the sleep opportunity?
  - Wrist-worn actigraph (sleep watch)
- Tier 3 – In the workplace, do they maintain adequate alertness and performance?
  - Palm Pilot Psychomotor Vigilance Task (PVT)

Public Policy Implications

- Short and mid term solution is fatigue risk management embedded in safety management
  - Science-based fatigue risk management systems (FRMS)
  - Make use of technology for monitoring actual sleep and real-time performance
- The long-term solution is automation of work performed during extended hours and on the back side of the clock
  - The ideal job according to Money Magazine is a software engineer
  - Flexible hours, work from home, self-paced, good pay
- Even current day shift timing may not be ideal

Point of Contact

Gregory Belenky, MD
Research Professor and Director
Sleep and Performance Research Center
Washington State University
P.O. Box 1495
Spokane, WA 99210-1495

Phone: (509) 358-7738
FAX: (509) 358-7627
Email: belenky@wsu.edu