The interaction of OSA, Fatigue, & Sleep: A Performance Model

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Operational Definition

DOT Human Factors Coordinating Committee, 1998

- Fatigue is more than sleepiness and its effects are more than falling asleep.
- **Fatigue** is a complex state characterized by a lack of alertness and reduced mental and physical performance, often accompanied by drowsiness.
Symptoms versus Root Causes

Symptoms

Operational Consequences

- Measurable Changes in Performance
- Lapses in attention and vigilance
- Delayed reactions
- Impaired logical reasoning and decision-making
- Reduced “situational awareness”
- Low motivation to perform “optional” activities
- Poor assessment of risk or failure to appreciate consequences of action
- Operator inefficiencies

Root Cause Analysis

- Fatigue is one potential root cause.
- No direct measure, physiological marker, or “blood test” for fatigue.
Modeling Provides an Objective Metric for Fatigue

- The conditions that lead to fatigue are well known.
- A fatigue model simulates the specific conditions and determines if fatigue could be present.
- The model can estimate the level of degradation in performance and provide an estimate of fatigue risk.
ALERTNESS & COGNITIVE PERFORMANCE

Time of Day

CIRCADIAN RHYTHM

Sleep History and Time on Duty

CUMULATIVE SLEEP DEBT

ALERTNESS & COGNITIVE PERFORMANCE

Daily Variations in Effectiveness
SAFTE

- The Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE) Model is based on 17 years of fatigue modeling experience.
- Validated against laboratory and simulator measures of fatigue.
- Validated and calibrated to predict accident risk by the Department of Transportation.
- Peer reviewed and found to have the least error of any available fatigue model.
- Accepted by the US DOD (Air Force, Army, Navy, Marines) as the common warfighter fatigue model.
Practical Software for Fatigue Assessment and Management

- Fatigue Avoidance Scheduling Tool (FAST)
- FAST is a fatigue assessment tool using the SAFTE model
- Developed for the US Air Force and the US Army.
- Department of Transportation has sponsored work leading to enhancements for transportation and industrial applications.
- DOT validated and calibrated.

- Now available as a tool for commercial applications.
Two-Step Sleep/Performance Model

- OSA
- Actigraph or Logbook
- Sleep Estimator
- Work Schedule

Sleep Input

Physiological Model
Questions

1. Can actigraphy detect sleep disturbances produced by sleep apnea?
2. Can actigraphy detect differences in severity of sleep apnea?
3. Do these differences translate into meaningful differences in estimated sleep and predicted performance?
4. Will exposure to feedback based on actigraphy and predicted performance reinforce greater CPAP use and adherence to treatment protocols?
Single Day of Activity, Example

Noon, March 24 to noon, March 25

Major Sleep Period – Time in Bed
Complete 24 hr Records for the Entire Month

Before CPAP

After CPAP
Focus on Sleep Periods Only

Before CPAP

After CPAP
Pre- and Post-CPAP Activity Patterns

Pre-CPAP: Noon, March 24 to noon, March 25

Post-CPAP: Noon, April 12 to noon, April 14

Major Sleep Period – Time in Bed
Sleep Quantity per Day

Sleep Hours Per Day (Two Days Means)

- Untreated Sleep Apnea
- CPAP Treatment

Days

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<th>Hours</th>
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<td>4/17/2006</td>
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- Untreated
- Treated

Sleep Hours Per Day (Two Days Means)
Sleep Fragmentation Before and After

Major Sleep Episodes per Day (Separated by > 2.5 min Awake)

<table>
<thead>
<tr>
<th>Untreated Sleep Apnea</th>
<th>CPAP Treatment</th>
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</table>

Days

Episodes

Days

CPAP Treatment

Days

Untreated

Treated

Episodes

Days


CPAP Treatment

Untreated Sleep Apnea

Episode counts before and after CPAP treatment.
How does this translate to better brain functioning and Performance?

- The principle effect of sleep loss is reduced cognitive ability and performance lapses.
- Difficult to measure directly.
- Fatigue model can predict how the “average” person’s performance would improve with increased of sleep.
- Performance feedback could be provided daily to reinforce adherence.
- Does this additional information matter?
Lapses (RT > 500ms)
Mean = 6.07
SD = 6.61

(Note: the ‘down’ periods (green) were calculated with the automatic option – to illustrate how this calculation fails for this data set)
Hypothetical “Normal” Sleeper

Performance while awake (black line) is always above 90%
Performance Estimate Based on Sleep Recording

Performance gradually improves to near ideal after the CPAP
Daily Tendency to Have Lapses

Pre-CPAP

Post-CPAP

Lapse Likelihood

Fully Rested Range
Proposed Studies

● Study 1: Descriptive analysis of actigraph recordings of patients with sleep apnea before and after CPAP treatment.

● Study 2: Controlled study of the benefits of sleep and performance feedback.

● Protocols have been developed and study is planned for the near future.
Questions?

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Experiment 1: Actigraphy Measures of Sleep Apnea and CPAP Therapy

Technological Proof-of-Concept/Validation

- Enroll equal numbers of patients diagnosed as Mild, Moderate, & Severe OSA. Case-control so that all groups are equivalent in as many parameters as possible prior to study. Ideally, we'd have a similarly case-controlled group of non-sleep-disordered subjects, but not necessary.

- Outfit each subject with Actigraph for continuous monitoring and provide a laptop or netbook computer for data upload:
  - 1-2 weeks of no CPAP baseline followed by 2-4 weeks of CPAP usage (realistically, one week of baseline + 2 weeks CPAP)
  - No feedback, simply record and upload the data
  - Analyze sleep parameters as a function of OSA severity with covariate of compliance rate.

- Answer the simple question: Does actigraphy detect sleep benefits of CPAP in OSA patients? If it does not, then feedback would be arbitrary and irrelevant. If it does, then proceed to Experiment 2.
Lapses (RT > 500ms)
Mean = 1.28
SD = 1.44
Experiment 2: Effects of Actigraphy Feedback on CPAP Compliance

- Enroll equal numbers of Mild, Moderate, & Severe OSA patients. Case-control and similar to Experiment 1.
- Outfit each subject with Actigraph for continuous monitoring and provide a laptop or netbook computer for data upload.
- Randomly assign half to Feedback or No Feedback conditions.
  - The No Feedback condition is identical to Exp 1.
  - In the Feedback condition, upon daily data upload, each subject receives a computer-generated report on their laptop with the following individualized data:
    - Line chart of total sleep, sleep efficiency, and wake episodes for each day of the study (accumulates as study period progresses)
    - SAFTE/FAST chart of predicted performance effectiveness (accumulates as study period progresses)
    - Performance effectiveness: % change from pre-CPAP baseline and % change from previous day
- If we want to save time and money, and we're not worried about time-of-year or other cohort effects, we could simply compare the feedback groups in Exp 2 to the subjects in Exp 1 who received no feedback, so long as they are equally case-controlled.
- Answer the Question: Does sleep and performance feedback increase compliance with CPAP therapy.