Defining, Measuring, and Predicting Fatigue

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Fatigue Operationally Defined ...

- Fatigue is operationally defined ...  
  - Subjectively by self-report, e.g., “I am tired.”
    - Karolinska Sleepiness Scale (KSS)
    - Samn-Perelli Fatigue Scale
  - Objectively by degraded performance, for instance
    - Psychomotor Vigilance Task (PVT)
    - FOQA-derived metric

- Fatigue is unmasked by increasing time on task

- Qantas simulator-based fatigue study
  - When fatigued better at detecting errors
  - When fatigued worse at managing errors
Fatigue a function of....

- Fatigue is function of three factors ...
  - Time awake (sleep/wake history) – in use
  - Time of day (circadian rhythm phase) – in use
  - Time on task (workload) – under development
  - .... All three are modulated by individual differences

- At a minimum to study fatigue we need
  - Objective measures of sleep
  - Objective measures of performance
Actigraph and Hand Held Psychomotor Vigilance Task (PVT)
Measuring Sleep with the Actigraph...
Measuring Performance with the PVT ...

12 Hours Awake
36 Hours Awake
60 Hours Awake
84 Hours Awake

Van Dongen and Hursh, 2011
An experiment...

![Graph showing Psychomotor Vigilance Task (PVT) Speed (1/RT) over time (24-Hour Clock). The graph displays a decline in speed with time, with N = 49.]
Fatigue as the Integration of Sleep Loss, Circadian Rhythm, and Workload

Wesensten, et al., 2004
Time Awake, Time of Day, and Time on Task

- Time of Day:
  - Sinusoidal Circadian Rhythm in Performance Modulates the Linear Decline in Performance caused by Increasing Time Awake

- Time Awake:
  - Linear Decline in Performance caused by Increasing Time Awake

- Time on Task:
  - 0800 h 1st Day
  - Time Awake = 1.5 h
  - Status - Rested

  - 0800 h 2nd Day
  - Time Awake = 25.5 h
  - Status - Sleep Deprived

Note: Increasing Time Awake and Circadian Nadir Interact to Amplify Time on Task Effects
Another Experiment ...
Sleep Restriction and Performance

Belenky, et al., 2003

n = 16-18/group
Mathematical Models ...

- Mathematical models integrate ...
  - Homeostatic sleep drive (time awake/sleep/wake history)
  - Circadian rhythm phase (time of day)
  - Workload (time on task)

- ... and individual differences

- Mathematical models combine sleep/wake history, circadian rhythm phase, and workload in order to predict performance
Activity, Sleep Scoring, Performance Prediction...
Integration of Fatigue Risk Management into Rostering and Scheduling

- Personal biomedical status monitoring
  - Sleep/wake history (by sleep watch)
  - Circadian rhythm phase (by technology TBD)
  - Predict performance in real time person by person (by biomathematical performance prediction model)
  - Validate with embedded performance metrics
    - Lane deviation (trucking)
    - Metrics derived from FOQA (commercial aviation)

- Integrate performance prediction into rostering and scheduling
  - Integrate into objective function of rostering and scheduling software
  - Optimize along with other constraints
Point of Contact

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Predicting Performance from Sleep/Wake History and Circadian Phase

- Linear Decline during Waking
- Charging Function during Sleep
- Circadian Rhythm
- Combined (decline, charge, circadian)

A Nap
Predicting Performance from Actigraphically-Derived Sleep Wake History