Assessing Individual Differences in Adaptation to Extreme Environments: A 36-Hour Sleep Deprivation Study

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BACKGROUND

- In space, astronauts may experience effects of cumulative sleep loss due to demanding work schedules that can result in cognitive performance impairments, mood state deteriorations, and sleep-wake cycle disruption.
- Individuals who experience sleep deprivation of six hours beyond normal sleep times experience detrimental changes in their mood and performance states. Hence, the potential for life threatening errors increases exponentially with sleep deprivation.
- We explored the effects of 36-hours of sleep deprivation on cognitive performance, mood states, and physiological responses to identify which metrics may best predict fatigue induced performance decrements of individuals.

SUBJECTS & METHODS

- Five subjects (3 men, and 2 women) participated in a 36-hour sleep deprivation study over a five day period:
  - Days 1 and 2 (training on computer performance task battery during a typical sleep-wake period)
  - Day 3 (onset of sleep deprivation period-0700 hours)
  - Day 4 (end of sleep deprivation period- 1900 hours, resume normal sleep cycle).
  - Day 5 (post-test measures on performance battery and mood scale.

Performance Tests and Mood Scale:

- Performance was measured on a computer using the Delta test battery that included seven subtests : 3-choice reaction time-60sec, code substitution-60sec, pattern comparison-60sec, preferred and non-preferred hand tapping-20sec each, grammatical reasoning-90sec, and spatial transformation-90sec.
- Mood alterations were evaluated using a 10-point visual-analog scale consisting of seven specific mood states (**Table 1**). Subjects rated each mood state by moving a slide bar in either direction (left/right arrow keys) toward the anchors at each end (e.g., bored, interested). Scores greater than 5 indicate a more positive mood state while scores less than 5 indicate more negative mood.
- Testing occurred at three-hour intervals during the 36-hour sleep deprivation period.

	Sleepy (0) .... Alert (10)
	Weary (0) .... Energetic (10)
	Very Low (0) .... Very High (10)
	Tense (0) .... Relaxed (10)
	Sad (0) .... Happy (10)
	Very High (0) .... Very Low (10)
	Unpleasant (0) .... Pleasant (10)

Table 1. Two mood dimensions were calculated from mood state scores: 1) *Activation (readiness to perform):* mean of fatigue, arousal, motivation and concentration. 2) *Affective (perceived readiness to perform):* mean of physical discomfort, elation, tension and contentedness.

Physiological Measures:

The BioHarness™ is a commercially available system designed to measure human electrocardiography, respiration rate, chest (skin) temperature, body posture and activity. The elastic chest strap attaches with Velcro and all amplifiers, battery and digital data storage are within a removable module (**Figure 1**). This system does not use adhesive electrodes, but signals are sensed through a unique "smart fabric" which rests on the skin. Bioharness data was collected on subjects 24 hours a day on each day of the study.

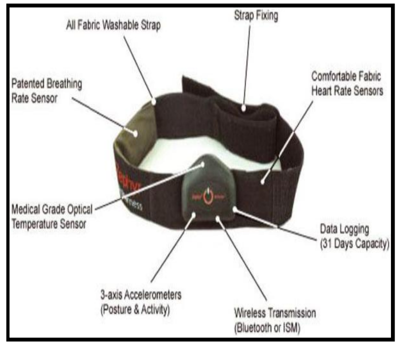

Figure 1. Zephyr BioHarness™ chest strap and module used to collect physiological measures.

Bioharness Data Processing:

- DADiSP graphical and analytical software was used to edit, reduce and transform the physiological data obtained from the Zephyr Bioharness ™.
- ECG data included noise artifacts that required visual inspection and manual editing (below).

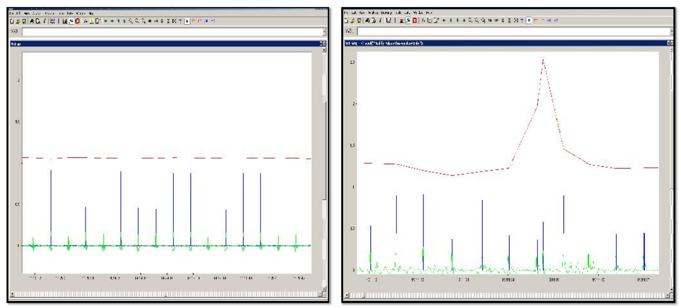

Figure 2. *(left)* Edited data using DADiSP. *(right)* Artifacts in ECG data due to a human reaction (i.e. coughing, sneezing, sudden movement, etc.) before editing.

RESULTS

- **Figure 3** shows a marked deterioration in the activation mood dimension for most subjects as sleep deprivation progressed which was followed by post-test recovery to baseline levels (training day). With the exception of subject 42 the affective mood dimension was least affected by sleep deprivation.

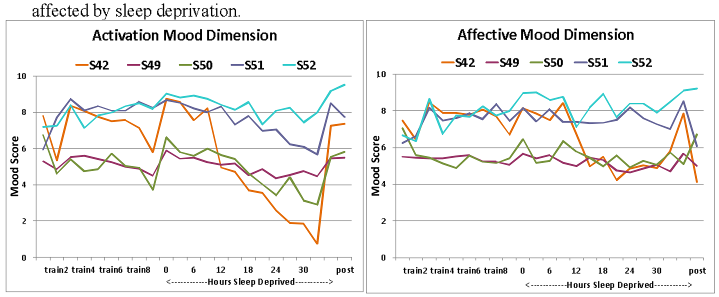

Figure 3. Activation (readiness to perform) and affective (perceived readiness to perform) scores for each subject.

- A shift in heart rate circadian cycles (Figure 4) was observed for each subject with levels remaining elevated after 22:00 hours on Day 3 compared to normal circadian cycles on Days 1 and 2. Large individual differences were also observed.

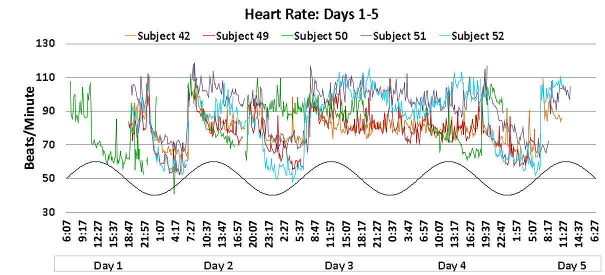

Figure 4. Sleep deprivation effects on heart rate. Sine wave (black) represents a normal 24 hour circadian cycle

- A composite performance index (Kennedy, 1997) was computed for each subject from subtest scores on reaction time, code substitution, preferred finger tapping, and grammatical reasoning. Composite performance (Figure 5) decreased for each subject relative to training trials 6-8 on Day 2, but varied in time of onset, severity of degradation, and rate of recovery following sleep deprivation.

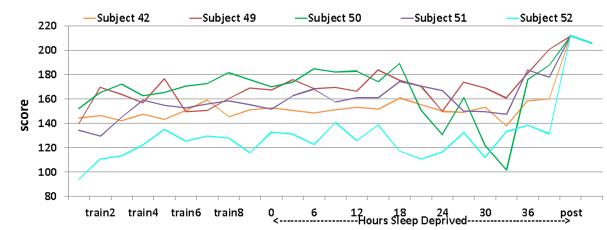

Figure 5. Delta composite performance index of each subject

CONCLUSIONS

- Converging indicators of performance, mood states, and physiological responses can be used to evaluate how well individuals adapt to extended wake periods.
- Understanding the effects of sleep deprivation on cognitive performance, mood, and physiology is crucial for long-term space flights.
- Continued research is essential to improving mission productivity, outcomes and to improve safety conditions in these individuals exposed to extreme environments.

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