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 disturbances, and sleep-wake cycle disruptions.
- 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: Amortized sleep deprivation period (4:00–1:00 hours)
  - Day 4: End of sleep deprivation period (10:00 hours, resume normal sleep cycle)
  - Day 5: Post-test on performance battery and mood scale

Performance Tests and Mood Scales:

- Performance was measured on a computer using the Delta test battery that included seven subtests: 1. choice reaction time (0.00sec), 2. code substitution (0.00sec), 3. pattern comparison (0.00sec), 4. preferred and non-preferred hand tapping (0.00sec), 5. each, 6. grammatical reasoning (0.00sec), and 7. spatial transformation (0.00sec).
- Mood alterations were evaluated using a 22-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 or right) until they reached the midpoint in each of the seven mood states.
- Scores greater than 5 indicate a more positive mood state while scores less than 5 indicate a more negative mood state.
- Testing occurred at three-hour intervals during the 36-hour sleep deprivation period.

<table>
<thead>
<tr>
<th>Mood State</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sleepy</td>
<td>0</td>
</tr>
<tr>
<td>Alarm</td>
<td>10</td>
</tr>
<tr>
<td>Very Low</td>
<td>20</td>
</tr>
<tr>
<td>Low</td>
<td>30</td>
</tr>
<tr>
<td>Tense</td>
<td>40</td>
</tr>
<tr>
<td>Sad</td>
<td>50</td>
</tr>
<tr>
<td>Very High</td>
<td>60</td>
</tr>
<tr>
<td>Happy</td>
<td>70</td>
</tr>
<tr>
<td>Excited</td>
<td>80</td>
</tr>
</tbody>
</table>

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

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 45, the affective mood dimension was most affected by sleep deprivation.

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 improving safety conditions in these individuals exposed to extreme environments.

REFERENCES