National Aeronautics and Space Administration

Evaluation of the Validity of Bio-Mathematical Models in Predicting Fatigue in an Operational Environment

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INTRODUCTION

- During long-duration space flights, crewmembers and ground-support staff experience irregular sleep schedules, erratic natural light patterns, and high workload due to mission demands.
- Such conditions can cause circadian misalignment and sleep loss, which in turn cause deficits in cognitive performance.
- The accuracy and usability of bio-mathematical sleep-wake models under conditions of non-traditional shiftwork is little known.

OBJECTIVE

To evaluate the validity of 3 sleep-wake models (e.g., the State-space Model, the Unified Model of Performance, and the SAFTE-FAST Model) designed to predict human performance and fatigue against objective measures of performance in the Human Exploration Research Analog (HERA), a spaceflight analog mission located at Johnson Space Center.

Model	Interface	Input Values	Input Data	Output
State-space	DOS-executable interface	Time, sleep/wake state	Sleep schedule (diary)	PVT Lapses
Unified	Web-based interface	Time, sleep/wake state, caffeine dose (optional)	Sleep schedule (diary)	PVT Lapses, PVT reaction time, PVT response speed
SAFTE -FAST	Standalone software program	Time, sleep/wake state, work schedule	Sleep schedule (diary)	Cognitive Effectiveness

Table 1. Description of model interface, possible inputs, input data, and output.

METHODS

- Four crews (n=16) inhabited the HERA for a period of 45 days.
- Each week, participants slept for 8 hours for two nights, then underwent a five-day period of 5-hour sleep restriction.
- Participants completed the Psychomotor Vigilance Task (PVT), a simple reaction time test assessing performance, 5 times a day every 3 days.

METHODS (cont.)

- Predictions from the three bio-mathematical models were compared to participants' actual PVT scores collected in the study by matching the time points from the model with the timing of each PVT session.

RESULTS

- Spearman rank correlations were calculated to examine association between model predictions and PVT data.

	PVT (Actual Performance)	State-space	Unified	SAFTE-FAST
PVT (Actual Performance)	1	-	-	-
State-space	0.07*	1	-	-
Unified	0.05	0.69**	1	-
SAFTE -FAST	-0.12**	-0.50**	-0.42**	1

Table 2. Correlation coefficients for PVT and three bio-mathematical models.
Note. * = p < 0.05, ** = p < 0.01

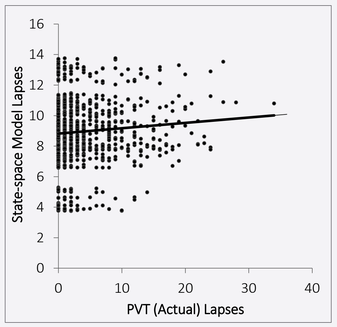


Figure 1. Correlation between PVT and State-space model.

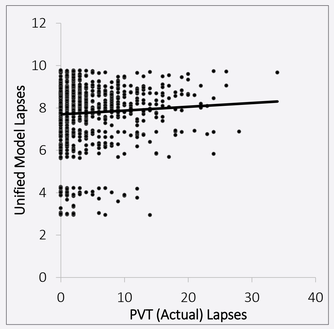


Figure 2. Correlation between PVT and Unified Model.

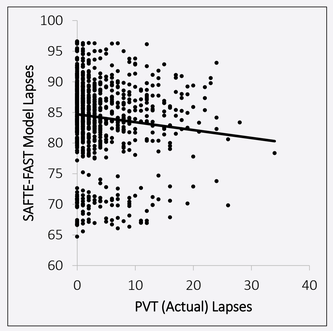
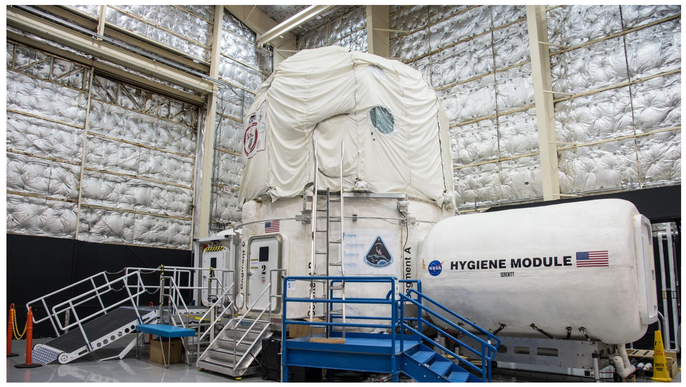


Figure 3. Correlation between PVT and SAFTE-FAST model.

- Weak trends were detected for two of the three bio-mathematical models.
  - **Positive association** between State-space model predictions and PVT lapses
  - **Negative association** between SAFTE-FAST Cognitive Effectiveness and PVT lapses.
- There was no correlation between the Unified Model and PVT lapses.
- All three models were highly correlated with one another.



DISCUSSION

- The present study examined associations between 3 bio-mathematical model predictions and actual performance in an operational environment.
- Both the State-space and the SAFTE-FAST models were significantly associated with the PVT.
- Evaluation of bio-mathematical models will help inform work scheduling and implementation of effective countermeasures (e.g., caffeine, lighting) to improve work efficiency and combat fatigue in future space exploration missions.

REFERENCES

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2. Gregory, K., et al. (*under review*). Comparison of fatigue predictions from four bio-mathematical models to psychomotor vigilance task data in short-haul daytime aviation operations.

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