SUBJECTIVE AND OBJECTIVE INDICATORS OF FATIGUE AS PREDICTORS OF PERFORMANCE ON A SUSTAINED-ATTENTION SONAR TASK

Sierra Nastasi[1,2], Krystina Diaz[1,2], Chad Pelter Ph.D.[2], Jeffrey B. Bolkhovsky Ph.D.[1], LCDR Mahamat Babagana Ph.D.[3], Sylvia Guillory Ph.D.[1]

1 Naval Submarine Medical Research Laboratory (NSMRL), Box 900 NAVSUBASE NLON, Groton, CT, 2 Leidos, Reston, VA 3. Naval Medical Research Unit Dayton

Introduction

Background: Military tasks require vigilance and accurate decision-making, yet fatigue can impair prolonged operational performance.[1,2]

Challenges: Non-invasive indicators of fatigue could predict performance decline. The contribution of transient fatigue states and stable individual characteristics to fitness-for duty outcomes, e.g., vigilance and operational performance, has not been fully examined.

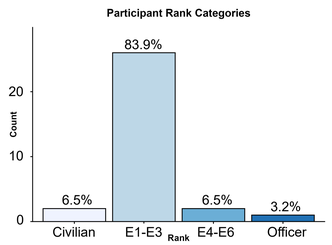
Objectives: Explore whether subjective state and trait measures predict vigilance performance on an operationally relevant task.

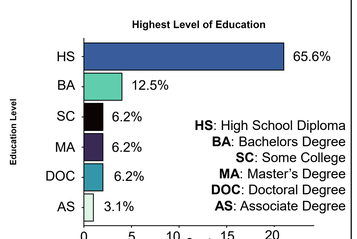
Predictions: State measures were expected to reflect short-term fluctuations in alertness, whereas trait measures should explain individual differences in susceptibility to fatigue-related performance impairments.

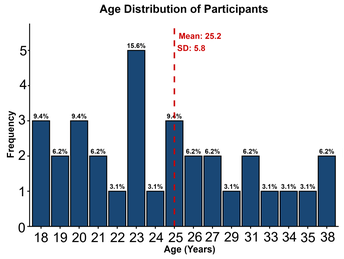
Method

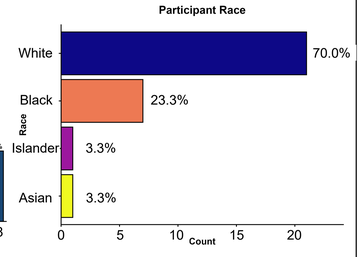
Participants:

35 participants recruited from Naval Submarine Base New London







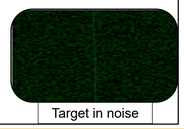


Procedure:

1. Fast for 4 hours before participation (to enable valid collection of saliva samples for analyses).
2. Complete a series of questionnaires:

Measure	Construct	Classification	Example Item (prompt)	Response Format
Epworth Sleepiness Scale[3]	Sleep Duration	STATE	"How many hours did you sleep last night?"	Numeric (hours)
Epworth Sleepiness Scale	Daytime Sleepiness	TRAIT	"What is the chance of nodding off while watching TV?"	0 = Would not nod off 3 = High chance
Lee Fatigue Scale[4]	Energy Levels	STATE	"Worn out / Energetic / Active"	1 = Not at all 5 = Extremely
Lee Fatigue Scale	Fatigue Levels	STATE	"Hungry / Tired / Sleepy"	1 = Not at all 5 = Extremely
Stanford Caffeine Questionnaire[5]	Caffeine intake	TRAIT	"Average caffeine consumed"	Numeric (mg/day)

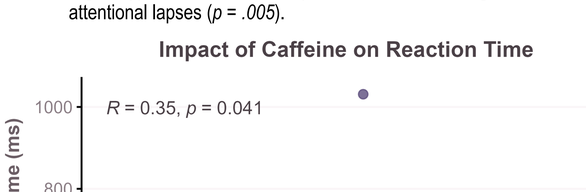
3. Complete a 10-minute psychomotor vigilance task (**PVT**) reaction time task
4. Complete a 60-minute simulated **sonar watch station task** where they identified signals embedded within visual noise
   - Classified targets as one of two vessel types based on the unique set of frequencies defining the vessel
   - Targets (60 vessels) were visible for 80 seconds



Target in noise

Results

PVT

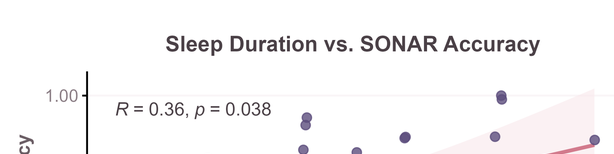


PVT Measures

Reaction Time (RT): 322.98 ± 133.17 ms

Lapses (responses > 400 ms): 3.29 ± 7.56 count

Sonar Watch Station Task



Sonar Measure

Accuracy: (# correctly classified vessels/All classified vessels): 0.67 ± 0.23 proportion

Associations between Subjective Responses and Behavioral Performance

Linear Regression	Composite of All Questionnaire	Sleep Duration	Daytime Sleepiness	Energy	Fatigue	Caffeine Intake
PVT Lapse	r = 0.05, *p* = .758	r = -0.05, *p* = .764	r = 0.06, *p* = .756	r = -0.05, *p* = .767	r = -0.02, *p* = .916	r = 0.48, *p* = <.01
PVT RT	r = -0.02, *p* = .916	r = -0.08, *p* = .640	r = -0.08, *p* = .673	r = -0.13, *p* = .468	r = -0.16, *p* = .380	r = 0.35, *p* <.05
Sonar Accuracy	r = -0.37, *p* <.05	r = 0.36, *p* < .05	r = 0.05, *p* = .795	r = -0.32, *p* = .070	r = 0.01, *p* = .936	r = 0.26, *p* = .138

Impact of Caffeine on PVT Lapses

Higher typical caffeine consumption associated with a greater number of attentional lapses (*p* = *.005*).

Impact of Caffeine on Reaction Time

Higher typical caffeine consumption associated with slower reaction times (*p* = *.041*).

Overall Q-Score vs. SONAR Accuracy

Higher baseline scores associated with lower accuracy (*p* = *.032*).

Sleep Duration vs. SONAR Accuracy

More hours of sleep associated with greater accuracy (*p* = *.038*).

Discussion

Discussion:

- Fasting for 4 hours prior prohibited the consumption of caffeine and may have resulted in difficulty maintaining attention on the PVT task.
- Participants with higher fatigue performed worse on the sonar task.
- Operational tasks may better characterize readiness than any individual measure.
- Participants with higher reported duration of sleep performed better on the sonar task.
- Adequate sleep is important for maintaining accurate stimulus. Submarine watchbill structures vary in length,[6] which may influence these operational capabilities.

Conclusions, Future Work, and Limitations

Conclusions:

- Greater habitual (trait characteristic) caffeine consumption increased response times when caffeine was withdrawn.
- Greater sleep duration (state characteristic) was associated with higher sonar performance, whereas trait fatigue scores were associated with poor classification performance.
- Inadequate sleep impedes a sonar task, as sonar technicians must maintain sustained attention.

Future Work:

- Explore how an abundance of caffeine/stimulants impact performance on sonar and PVT tasks.
- Examine whether genetic markers associated with sleep regulation and excessive daytime sleepiness contribute to individual differences in vulnerability to low performance.

Limitations:

- Reliance on self-reported sleep and fatigue measures may introduce reporting bias.
- Participants near or below chance on the classification task may reflect task difficulty, disengagement, or response strategy differences.

References:

1. Daley, G., Gever, D., Posada-Quintero, H.F., Kong, Y., Chon, K.H., & Bolkhovksy, J. (2020). "Onboarding Materials as Cross-functional Boundary Objects for Medical AI." *Frontiers in Artificial Intelligence*.

2. Chabal, S., Markwald, R.,& Chinoy, E. (2024). "Life Onboard a Submarine: Sleep, Fatigue, and Lifestyle Behaviors of Sailors on a Circadian-Aligned Watchstanding Schedule." *Applied Ergonomics*.

3. Johns, M. W. (1991). "A new method for measuring daytime sleepiness: The Epworth sleepiness scale." *Sleep*, 14(6), 540–545.

4. Lee, K. A., Hicks, G., & Nino-Murcia, G. (1991). "Validity and reliability of a scale to assess fatigue." *Psychiatry Research*, 36(3), 291–298.

5. Nova, P., Hernandez, B., Ptolemy, A. S., & Zeitzer, J. M. (2012). "Modeling caffeine concentrations with the Stanford Caffeine Questionnaire: Preliminary evidence for an interaction of chronotype with the effects of caffeine on sleep." *Sleep Medicine*, 13(4), 362–367.

6. Larter, D.B. (2016). "This 'Life-Changing' Shift Has Made Submariners Much Happier." *Navy Times*.

Disclaimer: The views expressed in this article are those of the author and do not necessarily reflect the official policy or position of the Department of the Navy, Department of Defense, nor the U.S. Government.
Source of support: This work was support by Military Operational Medicine Research Program (MOMRP) Joint Program Committee (JPC-5) F1710.
Human subject research protections: The study protocol was approved by the Naval Submarine Medical Research Laboratory Institutional Review Board in compliance with all applicable Federal regulations governing the protection of human subjects (expedited protocol: NSMRL.2024.0001).