Neural and Physiological Predictors of Operational Readiness in Rapidly Composed Military Teams

Jonathan Sussman-Fort[1], Jeremiah Folsom-Kovarik[1], Jeffrey Craighead[1], Angela Woods[1], Daniel Wilson[1], Stephen Kline[1]
Nick Petroff[1], Dylan Schmorrow[1,] Tanner Hilsabeck[1], Joseph Cohn[1], Bradly Stone[1], Eduardo Salas[2], Lila Berger[2]
Maha Khalid[2], Rylee Linhardt[2], Abby West[2], Chris Berka[3], Ella Thunen[3], Silke Dodel[4]
[1]Lyntris, [2]Rice University, [3]Advanced Brain Monitoring, [4]Deep Science

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Introduction

The ability to measure and predict expert team performance is essential for assessing military operational readiness. The goal of this work is to identify and characterize an objective physiologic signature of team performance to predict operational readiness.

We present our results based on 2 data collection events from eight, five-member Marine Fire Support Teams (FiSTs) engaged in virtual simulation-based training with analysis based on operationalizing *Team Behavioral Competency Theory (TBCT)*, empirically tested across military, aviation, and healthcare settings.[1]

Key Findings

For n= 36 missions, across 8 FiSTs we predict subjective instructor ratings using objective neural and physiologic and behavioral markers with:

Mission Overall Prediction	**92%**
Mission Subtask Prediction	**92%**

Methods

Participants: Eight Marine Corps Fire Support Teams (FiST) from the Marine Ground Air Combat Center (MGACC) at Twentynine Palms, CA.

Testing: Each FiST completed hour-long simulations with the Xiphos JTAC Virtual Trainer (JVT) system[2] and were rated by instructors based on a scoring rubric.[3]

Fig. 1: FiST team during mission scenario with sensor systems

Data collection:

- Standard electroencephalogram (EEG) neural recordings (20-channels) mobile, wireless B-Alert® X24 system with single channel electrocardiogram (ECG)
- High-resolution tripolar concentric ring electrodes (4-channels) (tEEG), to pinpoint team network level brain activity from deeper brain regions
- Desktop monitor mounted Tobii eye tracker nano
- Video web cameras, audio lapel mics for monitoring

Analyses

Data cleaning: Visual inspection of artifacts, notch filter at 60Hz to remove line noise and ICA for eye-blink and muscle artifact removal.

Derived Features: Interbrain neural synchrony measures, role-based composite physiologic and neural features, bottom-up neural dimensionality features and voice disfluency features.

Behavioral Windows: *Mission Brief* and *Attention to FiST* team behavioral activity

Feature Identification: Team features within behavioral windows tested as feature inputs to a causal model to compute team performance predictions.

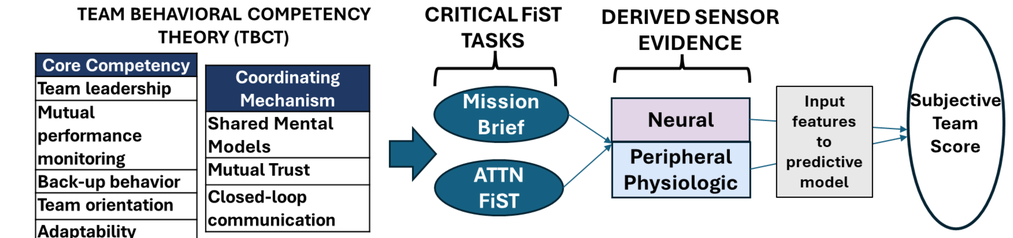

Fig. 2: Causal model - TBCT linked to FiST tasks, derived features and team performance

Results

Eight total FiSTs (n=36 missions, split across 3 mission scenarios)

Prediction Target	Subset	Outcomes	MAE	RMSE	Accuracy	F1
Mission Rating Overall	training	3	0.075	0.179	0.949	0.956
Mission Rating Overall	holdout	3	0.340	0.386	0.917	0.889
Mission Rating Subtasks	training	12	0.149	0.341	0.951	0.951
Mission Rating Subtasks	holdout	12	0.340	0.422	0.924	0.908

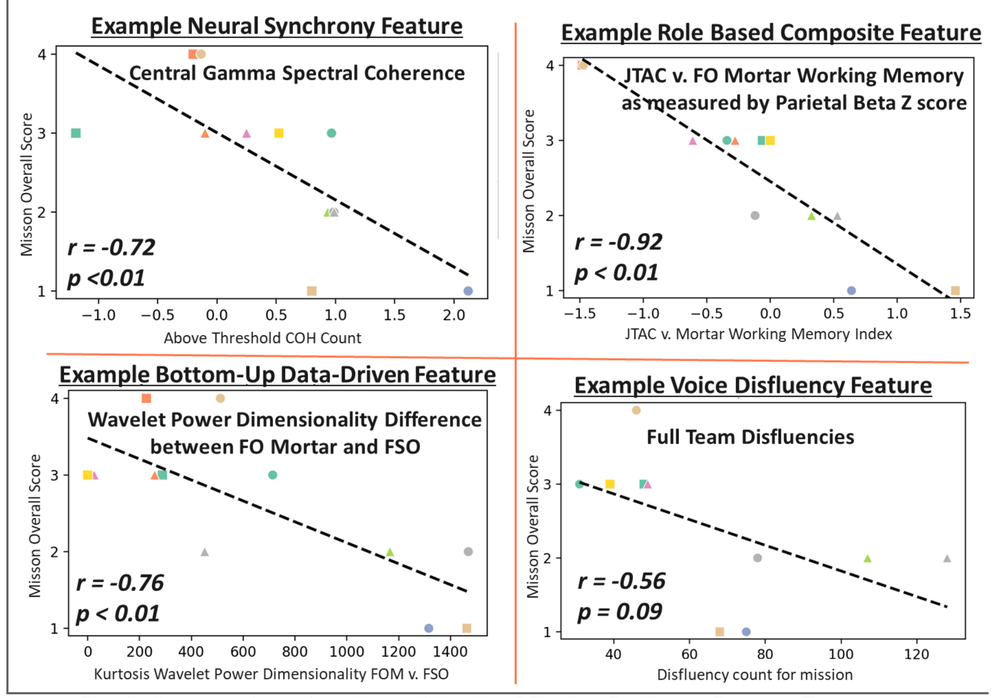

Fig. 3: Scatter plots showing subjective Mission Rating v. Feature Types

Conclusions

Takeaway 1: TBCT provided a practical framework for linking mission behaviors to measurable team-state indicators. The framework helped organize the analysis around leadership, mutual performance monitoring, back-up behavior, team orientation, and adaptability rather than around sensor outputs alone.

Takeaway 2: The findings support a causal hypothesis consistent with the idea that team cognitive-coordination state during mission-critical windows contributes to team performance.

Limitations: 1) Results do not prove causation and the present observational design cannot determine whether the identified features directly cause performance changes. Some features may reflect shared stimulus processing, scenario difficulty, team experience, instructor expectations, or other unmeasured factors. A stronger causal claim would require experimental manipulation, prospective validation, or intervention studies..[4-6]

Limitations: 2) The sample size was limited to n=36 missions. This limits broad generalization and increases the need for cautious interpretation, despite collection in an operationally relevant training environment,

Future Efforts and Mitigations will focus on prospective validation, larger datasets, and controlled tests of the causal relationships suggested by the current predictive model. The long-term objective is an instructor-facing readiness assessment approach that augments expert judgment with interpretable, objective, multimodal evidence of team performance and readiness.

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