Measuring the Neurodynamic Organization of Teams

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Background and Goals

• Across-brain neurodynamic synchronizations / organizations arise when teams perform coordinated tasks, but little is known about the frequency, magnitude, and duration of these organizations and their relationships with other performance variables.

• We describe a symbolic electroencephalographic (EEG) approach that fills this gap by providing second-by-second quantitative estimates of the neurodynamic organization of teams.

• Our studies show that neurodynamic models developed for US Navy submarine navigation teams can distinguish between high and low resilience teams as measured by a US Navy rubric.
Modeling Rationale: Brain Entrainment and Across-Brain Synchronizations

• Brain entrainment refers to the brains electrical response to external sensory stimulation.
  • Simple entrainment is where an external stimulus influences the group dynamics, e.g. a repeating sound.
  • More complex brain region entrainment is seen across individuals while watching the same scenes in a movie.
• Question: Are teams similarly entrained by teamwork?


Brain activations to ‘The Good, The Bad, and The Ugly’


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Submarine Piloting and Navigation (SPAN) – A Required, Complex, and Realistic Activity

- **Briefing**  ~15 minutes – map out the mission and training goals

- **Scenario**  60 – 120 minutes - SPAN contains periodic tasks like ‘Rounds’ that repeat every 3 min as well as less predictable situations, environmental changes, high traffic density, and instrument failures.

- **Debriefing**  20 – 40 minutes – an open discussion of what worked and what could be improved
## Evaluating Team Resilience: the Submarine Team Behavioral Tool (STBT)

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<tr>
<th>Un-Stressed Battle Rhythm</th>
<th>Leader Dependent Battle Rhythm</th>
<th>Team-Based Resilience</th>
<th>Advanced Team Resilience</th>
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<td>Routine Watch Team</td>
<td>Section Tracking Party</td>
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<td><strong>(Resilient)</strong></td>
<td></td>
<td><strong>(Brittle)</strong></td>
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### Levels of Team Resilience

**Submarine Team Behaviors Tool (STBT)**

- **Advanced Team Resilience** - Required to manage multiple dynamic problems.
- **Team-Based Resilience** - The ‘routine stays routine’ even during stress.
- **Leader-Dependent Battle Rhythm** - Teams retain their battle rhythm even under stress, but only because someone takes charge.
- **Unstressed Battle Rhythm** - Teams can exhibit battle rhythm, but only in the absence of disruptions.

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Subjects and Data Collection

• The crew members of the 24 teams participating in the EEG studies were:
  • Quartermaster, Navigator, Officer on Deck, Assistant Navigator, Contact Manager, Radar.

• X-10 EEG headset from Advanced Brain Monitoring, Inc. used with sensors located at: F3, F4, C3, C4, P3, P4, Fz, Cz, POz in a monopolar configuration.

• EEG was collected and 1-40 Hz Power Spectral Density (PSD) bins created around each 1 Hz EEG frequency; these forty bins served as the input data for subsequent modeling.

• This results in large data sets – 40 frequency bands x 6 persons x 10+ electrode site combinations.
Neurodynamic Symbol (NS) Streams Simplify the Large Data Problem

1, 2. Create Neurodynamic Symbols and State Space - Individual symbols show the relative levels of an EEG marker for each team member, state spaces contain the most representative symbols.

3, 4. Analyze Temporal NS Expression & Create Entropy Models - NS expression is plotted each second for the performance.

NS Data Streams Have Temporal Structure
Neurodynamic Organization Increased When Resilience was Tested

• Three dimensional team coordination maps that plot the levels of NS entropy vs. EEG frequency vs. time.
  • The contours show the momentary fluctuations in team synchrony for each of the forty 1 Hz PSD bins.
  • These periods are linked with team activities and task events.
  • One of the activities is ‘Rounds’ which is a process the crew uses when establishing the boat’s position; this
The level of neurodynamic organization was highest in the Debrief and lowest in the Scenario.

Randomizing the NS streams prior to calculating entropy removed the synchronized activity.

There was little synchrony in the $\delta$ and $\theta$ frequencies.

N=10 teams of all skill levels.
Team Synchrony is Correlated with Team Resilience

- Seven SPAN teams were simultaneously rated for resilience using the US Navy adopted Submarine Team Behavior Toolkit.
- In the Briefing, resilient teams were *more synchronized*, i.e. high STBT scores were negatively correlated with NS entropy.
- In the Scenario, resilient teams were *less synchronized*, i.e. there were positive correlations, with high STBT scores correlated with high NS entropy.
- n=7 teams, ~16 hrs. of teamwork
Towards a Quantitative Neurodynamics Framework for Team Performance

- Inexperienced teams under stress are rigidly organized.
- Novice (zero history) teams have more random organizations.
- Experienced teams have a more fluid organization, allowing efficient performance of routine duties while having the flexibility to adapt to novel situations.
References


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