Triangulating Metrics for Assessing Macro-Level Cognitive States: Pushing the Way Forward

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What is Macrocognition?

**Basic Assumptions**
- Involves development, refinement, and maintenance of higher order cognitive processes and emergent states
- Complex, multi-level phenomenon
- Involves internalized and externalized processes
- **Reciprocal**, cyclical sets of IPO cycles
- Not constrained by where cognition occurs, but constrained by task characteristics

**Major Macrocognitive Processes**
- Individual Knowledge Building
- Team Knowledge Building
- Developing Shared Problem Conceptualizations
- Team Consensus Development
- Outcome Appraisal
Individual and Team Knowledge Building

- Pattern Recognition
- Recognition of Expertise
- Recognition of Expertise
- Sharing unique knowledge

Development of Shared Problem Conceptualization

- Build Perceptual Understanding
- Visualization of Data Meaning
- Build Conceptual Understanding
- Knowledge Sharing & Transfer

Consensus Development

- Intuitive Decision Making
- Mental Simulation
- Negotiation of Solution Alternative
- Storyboarding

Outcome Appraisal

- Fiore et al (in press)
What Are We Trying to Accomplish?

Methodological Questions

- What are the components within macrocognition that are both conceptually and practically significant?
- What guidance can we give researchers and practitioners alike in terms of measurement and the tools in our toolkit?
Our Approach

Constructs
Shared mental models, Transactive memory, Team member schema similarity, Team situation awareness, Common intent, Common ground, Team metacognition

Content/Focus
- Equipment,
- Task,
- Team,
- Expertise,
- Teamwork,
- Temporal, Strategic
- External elements,
- Higher order goals

Moderators

Effectiveness Criteria
- Construct validity
- Unobtrusive
- Incremental predictive validity
- Sensitivity
- Flexible

Method
- Elicitation
- Aggregation
## Outcomes

### Conceptual Delineation

<table>
<thead>
<tr>
<th>Macro-Level Emergent Cognitive States</th>
<th>Primary Focus</th>
<th>Primary Knowledge</th>
<th>Temporal Dynamics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Team Member Schema Similarity</td>
<td>- Taskwork</td>
<td>- Declarative</td>
<td>- Fairly Static</td>
</tr>
<tr>
<td></td>
<td>- Teamwork</td>
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<td>- Team interaction</td>
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</tr>
<tr>
<td>Common Intent</td>
<td>- Strategic goals &amp; expectations</td>
<td>- Strategic</td>
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<tr>
<td>Shared Situation Awareness</td>
<td>- Environmental elements</td>
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</table>

### Empirically-Based Heuristic

<table>
<thead>
<tr>
<th>Method</th>
<th>Content</th>
<th>Elicitation</th>
<th>Aggregation Method</th>
<th>Potential Moderators &amp; Mediators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathieu et al. (2000)</td>
<td>Task</td>
<td>Declarative</td>
<td>Pairwise ratings</td>
<td>Self-report</td>
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<tr>
<td>Espevik et al. (2006)</td>
<td>Equipment</td>
<td>Declarative</td>
<td>Questionnaire</td>
<td>Self-report</td>
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<tr>
<td>Marks et al. (2000)</td>
<td>Team interaction</td>
<td>Procedural</td>
<td>3-way overlap</td>
<td>Self-report</td>
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<td>3-way overlap</td>
<td>Concept mapping</td>
<td>Self-report</td>
</tr>
</tbody>
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- 2 person teams
- Flight combat sim.
- Novice, lab
- 6 person teams
- Tactical submarine sim.
- Active duty officers
- 3 person teams
- Apache helicopter sim.
- Novice, lab
- 3 person teams
- Tank sim.
- Novice, lab
### Sample Conceptual Delineation

#### Macro-Level Emergent Cognitive States

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## Sample Heuristic Development

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</thead>
<tbody>
<tr>
<td>Mathieu et al. (2000)</td>
<td>Construct Validity</td>
<td>Knowledge Type</td>
<td>Emergent Outcome(s) Focus on Method Source Aggregation Method</td>
<td>Task/Team Properties</td>
</tr>
<tr>
<td></td>
<td>Task Team</td>
<td>Declarative</td>
<td>Sharedness Pairwise ratings Self-report UCINET- QAP correlation (task had two members)</td>
<td>2 person teams Flight combat sim. Novice, lab</td>
</tr>
<tr>
<td>Espevik et al. (2006)</td>
<td>Equipment Team Team interaction</td>
<td>Declarative</td>
<td>IPK Questionnaire Self-report N/A</td>
<td>6 person teams Tactical submarine sim. Active duty officers</td>
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<td>Marks et al. (2000)</td>
<td>Team interaction</td>
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<td>3-way overlap Pairwise ratings Self-report Pathfinder C index for each pair of team members averaged</td>
<td>3 person teams Apache helicopter sim. Novice, lab</td>
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<td>3-way overlap Concept mapping Self-report % of shared concepts placed identically on map</td>
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Extraction of Guidelines (Sample)

**High Level Guidelines**
- **Guideline 1**: Measures of team cognition should be unobtrusive.
- **Guideline 2**: Measures of team cognition should be flexible.
- **Guideline 3**: Measures of team cognition should be examined for incremental predictive validity.
- **Guideline 4**: Multiple methods and referents should be used to examine aspects of team cognition within a single study.
- **Guideline 5**: Method of aggregation should be driven by theory.

**Specific Guidelines**
- **Guideline 6**: To fully capture the complexity of shared SA the following elements should be included in measurement tools: the perception of elements in the environment, meaning of such elements, and predicting future scenarios.
- **Guideline 7**: Measures of shared mental models should assess complementarity of beliefs, accuracy, and awareness of fellow members perceptions.
Emerging Lessons

- Lack of construct clarity
- Typical manner of elicitation for shared mental models includes questionnaires, vignettes, pairwise comparisons, concept mapping, card sort, textual analysis, interviews, and communication analysis
- Typical manner of elicitation for shared situation awareness includes: questionnaires, verbal and written probes, observational event-based checklists
- Typical manner of elicitation for transactive memory systems include: questionnaires, communication analysis, observation

- Constructs often not completely measured (see conceptual definitions)
- Primary focus on emergent states; lack of attention to development of team cognition or corresponding cognitive processes
- Incremental validity often not tested
  - Across and within constructs
- Content and method often confounded
- Over reliance on self report and single method
- Some indications that method does make a difference in some instances (Messmer-Magnus & DeChurch, 2007)