Enhancing Team Performance for Long-Duration Space Missions

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NASA BHP Team Risk

• Risk of team performance decrements due to inadequate
  – Cooperation
  – Coordination
  – Communication
  – Psychosocial Adaptation

• Potential issues in space
  – System failures in habitat
  – EVA gear
  – Health of crew: illness, injuries
  – Space threats
  – Psychosocial conflicts/tensions

High-Risk Environments
Preface - Historical Research Shifts

Naturalistic Decision Making (not analytic, lab based)  
Teams (subset of groups)  

KNOWLEDGE  
+  
PROCESS  
↓  
TEAM PERFORMANCE  
Efficiency  
Accuracy

Overview

I. Features of Effective Team Cognition  
   – Shared Mental Models  
   – Collaborative Decision Making  
     • NDM  
     • Risk Assessment  
     • Metacognitive Strategies  
     • Communication  
   – Teamwork  
     • Social processes  
     • Cohesion  

II. Challenges to Effective Team Cognition  
   – Limits of expertise  
   – Individual stress effects  
   – Sleep deprivation  
   – Interpersonal stresses  
   – Diversity factors  

III. Supporting Effective Team Cognition  
   – Training  
   – Support tools
I. Features of Effective Team Cognition

Some definitions

- **Teams**: Two or more individuals with specified roles interacting adaptively, interdependently, and dynamically toward a common and valued goal. (Dyer, 1984; Salas, et al., 1992)

- **Coordination**
  - Tasks are largely procedural, with specific subtasks assigned to different members of the team. Often scripted contributions

- **Collaboration**
  - Tasks are non-procedural. Contributions to joint problem solving, decision making or task completion involve unscripted contributions

- **Cooperation**
  - Team orientation, motivation to work together as a team

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I. Features of Effective Team Cognition

Shared Mental Models

- **Mental Models**
  - Understand, explain, predict
  - Models for
    - System
    - Tasks
    - Procedures - including roles & responsibilities
    - Teamwork - interaction and coordination processes
    - Individual team members
I. Features of Effective Team Cognition

Shared Mental Models

• How much overlap? Original view

Goal = Maximize overlap

New View of “Shared” Knowledge

+ Shared GOALS

Shared = Common + Complementary
I. Features of Effective Team Cognition

Collaborative Decision Making

• **Needed to cope with unexpected events**
  – E.g., UA 232, Apollo-13

• **Difficult events**
  – Ambiguous cues
  – Dynamic conditions --> shifting goals
  – Uncertain outcomes
  – High workload
  – Time pressure

I. Features of Effective Team Cognition

Collaborative Decision Making - NDM

• **Two major components**
  – Assess the situation
  – Choose a course of action

• **Recognition-Primed Decisions (RPD)**
  – Knowledge-based
  – Good under time pressure
  – Serial vs. concurrent comparison of options
  – (Klein, 1989, 1993)
I. Features of Effective Team Cognition

Collaborative Decision Making - Aero DM

• Risk Assessment
  – Implicit process - but evident in data
    • Monitoring - challenging study
    • MIT-LL study: pilots diverting around thunderstorms
  – Make explicit: low-fidelity sim study

Captain: “Smell the rain. Smell it?”
First officer: “Yup. Got lightning in it too.”

“Managers pursue risky actions because they fail to perceive accurately the risks involved.”

(Rhoda & Pawlak, 1999)
Risk perception drives action

**Half Empty**
Focus = negative:
Weather approaching Windshear likely
Avoid risk -> CHANGE plan
Action: Delay departure until weather improves

**Half Full**
Focus = positive:
Windshear diminishing
Accept mitigated risk-> CONTINUE with plan
Action: Review takeoff windshear procedures, Adjust T/O configuration

How Do Pilots Manage Risks?

All decisions aimed at PREVENTING LOSS while achieving GOALS

- **AVOID safety risk**
  - Delay takeoff or divert

- **MITIGATE safety risk**
  - Request priority handling to avoid fuel critical situation

- **Prepare for worst case**
  - Take precautions (e.g., review windshear procedures)
I. Features of Effective Team Cognition

Collaborative DM - Metacognitive Processes

• **Awareness of demands of situation + crew resources available to meet them**
  • Core of ADAPTIVE processes
    – Critical to
      • High workload situations
      • Unfamiliar situations
      • Ambiguous cues/incomplete information
      • Uncertain outcomes
  • C.f. Cohen, Freeman & Wolf (1996)
    – Recognitional/Metacognitive training - Mil C2

Collaborative DM - Communication Processes

• **Taskwork**
  – Share information - explicit (build shared sit model)
  – Closed loop
  – Efficient: Grice’s maxims

• **Teamwork**
  – Briefings
    • CDR’s intent, strategies, plans, contingencies
    • Involve all crewmembers
  – Error correction (Monitoring/challenging)
    • Maintain positive crew climate - fix problem
  – Relational communication
    • Important to cohesion
  – INDIRECT techniques to assess
    • C.f. EXEMSI (Cazes, Rosnet, Bachelard, Le Scanff, Rivolier (1996))
I. Features of Effective Team Cognition

Collaborative DM - Communication Processes

![Graph of TASK-ORIENTED and EXPRESSIVE](image)

**Unified Team (328)**

![Graph of TASK-ORIENTED and EXPRESSIVE](image)

**Tending to Polarize Team**

II. Threats to Effective Team Cognition

- Evidence of poor team cognition?
  - Limits of Expertise (Dismukes, Berman & Loukopoulos, 2008)
    - Unfamiliar problems
    - Difficult situations: competing goals, no good options
    - PCE - Why?
      - Fail to update models
      - Poor team process
      - Monitoring-Challenging

![Distribution of Error Types Across Original and Present Datasets](image)

Table 2. Distribution of Error Types Across Original and Present Datasets

<table>
<thead>
<tr>
<th>Error Category</th>
<th>% Total Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Procedural - PR*</td>
<td>23.1</td>
</tr>
<tr>
<td>Tactical decision – TD</td>
<td>16.8</td>
</tr>
<tr>
<td>Aircraft handling – AH</td>
<td>15.2</td>
</tr>
<tr>
<td>Situation awareness – SA*</td>
<td>5.9</td>
</tr>
<tr>
<td>Systems operation – SO</td>
<td>4.6</td>
</tr>
<tr>
<td>Communication – CO</td>
<td>4.3</td>
</tr>
<tr>
<td>Resource management – RM*</td>
<td>3.6</td>
</tr>
<tr>
<td>Navigational – NV</td>
<td>1.9</td>
</tr>
<tr>
<td>Secondary errors</td>
<td></td>
</tr>
<tr>
<td>Monitoring &amp; challenging – MC</td>
<td>22.8</td>
</tr>
</tbody>
</table>

* p < 0.025
II. Threats to Effective Team Cognition

**Inherent in Distributed Teams**

- Alternative perspectives
  - Differences in goals, risk perception, expertise
  - Pilots - ATC
    - Risk perception and action
    - Breakdowns (Beaman et al., 2005; in press)
      » Informational, Operational, Cognitive

<table>
<thead>
<tr>
<th>Informational Conflict</th>
<th>Cognitive Conflict</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difference in weather information</td>
<td>Difference in weather evaluation</td>
</tr>
</tbody>
</table>

- Inherent in Distributed Teams

**Individual stressors**

- Loss of cognitive resource
- Focus shifts to own highest priority - Lose team orientation
  - Driskell & Salas

**Sleep deprivation**

- Indirect cognitive effects rel to DM
  - Information updating failures
  - Underweight new information
  - Rigidity - loss of cognitive flexibility
  - Degrades mood
- Affects communication
  - Less task-relevant information transferred
  - Less discussion of strategies
  - Comprehension degrades
  - Simplified vocabulary - pronominalization
    - “How’s IT coming along up there?”
II. Threats to Effective Team Cognition

- **Interpersonal stress - conflict**
  - Failures to monitor each other, back up, correct errors
  - Reduced information sharing
  - Withdraw social / emotional support
  - Lose team orientation

- **Social pressures**
  - Status, face
    - B-747 study
    - USS Greeneville sinks Ehe

- **Diversity pressures**
  - SFINCSS
  - Mt. Everest

III. Supporting Effective Team Collaboration

- **Training**
  - Turn a TEAM of EXPERTS into an EXPERT TEAM
    - Self-managing, adaptive, flexible
  - Integrate TEAMWORK training w/ TECHNICAL
  - TEM = Threat and Error Management
    - Updated CRM
  - Validated Approaches
    - TACT (Team Adaptation and Coordination Training)
    - TDT (Team Dimensional Training)
    - Cross-Training
    - Interpersonal Training
    - Team Development (cohesion)
    - Multicultural
  - Meta-analysis of training approaches: Salas, DiazGranados, Klein, Burke, Stagl, Goodwin, & Halpin (2008)
    - Pos effects on team cognition, affect, process and performance
III. Supporting Effective Team Collaboration
TACT, TDT

- **TACT** *(Serfaty, Entin, & Johnson, 1998)*
  - Adjust coordination and communication strategies to maintain successful task performance under high WL and time pressure
  - Grounded in
    - Shared situation models
    - Team metacognition
    - Mutual team models of interacting team members’ tasks and abilities, including stress and WL
  - Generate shared expectations for how situation will evolve
  - Reduce communication overhead
    - Implicit coordination
    - Anticipation ratio of information sharing/requested info

- **TDT** *(Smith-Jentsch, Zeisig, Acton & McPherson, 1998)*
  - Similar to TACT but --
  - **Team self-diagnosis, correction and debriefing skills**
  - **Four dimensions**
    - Information exchange
    - Communication
    - Backup (supporting behaviors)
    - Initiative/leadership
  - **Validation study**
    - More accurate teamwork MM
    - More effective outcomes
III. Supporting Effective Team Collaboration

Cross-Training

- **Important for LD space missions**
  - Limited number of crew
  - Cover if one member is disabled

- **Rotate positions in training**
  - Taskwork vs. teamwork training

- **Most critical when**
  - High team WL
  - Tasks must be reallocated
  - Contributes to implicit coordination
  (Cannon-Bowers, Salas, Blickensderfer & Bowers, 1998)

- **Measuring Team Knowledge**
  - Teamwork training develops best in context of Taskwork training
  - Full cross-training better than conceptual cross-training

III. Supporting Effective Team Collaboration

Interpersonal Skills, Team Building

- **Fosters cohesion**
  - Working with others
  - Leadership
  - Positive communication
  - Conflict management

- **Evaluation - business environments**
  - Meta-analysis: IST had greatest benefits to productivity, cohesion, morale, job satisfaction

- **BUT other meta-analysis**
  - Team development/affect = most difficult to impact
  - Compared IST w/other training approaches: TACT etc.
  - Do NOT have good understanding of how to develop cohesion
    - Hint: Transformational Leadership is key
III. Supporting Effective Team Collaboration

Technology Supports

- **Distributed teams**
  - Locally distributed (within space crews)
  - Crew - ground (no time lag)
  - Crew - ground (time lag)
- **Face-to-face vs. Video vs. Audio**
  - Maintain team SA and collaboration
  - Face to Face (F2F)
    - Understand others’ actions, intentions
    - Computer-mediated = F2F for idea-generation
    - Lack of F2F
      - Difficulty in establishing conventions
      - Neg impact on performance on complex tasks / judgments
  - Video
    - Facilitates problem solving vs. email
    - Contributes to cohesion among distributed team members
  - Audio, Email
    - OK when no time restrictions
    - OK when onboard info is adequate
III. Supporting Effective Team Collaboration
Technology Supports

- **Asynchronous collaboration**
  (Krauss & Bricker, 1966; Kraut, Fussell, Brennan & Siegel, 2002)
  - Time lags in Mars communication
  - Even small delays affect establishment of common ground
  - Requires more explicit message formulation
  - Reduces efficiency, especially w/complex problem

- **Autonomous crew performance**
  - Requires onboard information systems
    - Easily searchable data architectures
    - Access to relevant systems data
    - Simplified procedures
    - Support medical care
  - On-board countermeasures
    - Psychosocial support
    - Conflict management

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Graphical representation of high-level relationship between the ‘Big Five’ and coordination mechanisms

[Diagram showing relationships among Team Leadership, Mutual Performance Monitoring, Team Orientation, Back-Up Behaviour, Adaptability, Mutual Trust, Shared Mental Models, and Closed Loop Communication.]

Salas, Sims, & Burke, 2006
Questions?

- I look forward to your input
- Judith.Orasanu@nasa.gov

We all THANK YOU!

Happy campers
**Distributed Problem Solving in Aviation**

- Flight crews
- ATC
- Airline Ops Centers

- Naturalistic DM
- Shared mental models
- Error detection & correction
- Risk perception/DM
- Conflict resolution