Enhancing Team Performance for Long-Duration Space Missions

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Exploration Missions: Unforgiving Isolated and Confined Environments, Stressors
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 = Common + Complementary

+ Shared GOALS
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

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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)
Collaborative Decision Making - Aero DM

I. Features of Effective Team Cognition

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.”

(Rodrigues & Liebman, 1997, p. 22)
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

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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
  - 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**

![Image of communication diagrams]

**Unified Team (328)**

**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

**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><strong>Primary errors</strong></td>
<td></td>
</tr>
<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>2.3</td>
</tr>
<tr>
<td>Resource management – RM*</td>
<td>3.6</td>
</tr>
<tr>
<td>Navigational – NV</td>
<td>1.9</td>
</tr>
</tbody>
</table>

| **Secondary errors**           |                |
| Monitoring & challenging – MC  | 22.8           |

* x < 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 (Bearman 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>

<table>
<thead>
<tr>
<th>Cognitive Conflict</th>
</tr>
</thead>
<tbody>
<tr>
<td>Different evaluation of safety</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Operational Conflict</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difference in plans for the aircraft</td>
</tr>
</tbody>
</table>

- **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


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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
### Team Effectiveness Framework

#### 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 with complex problems

- **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

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**THE CORE**

- Team Leadership
- Mutual Performance Monitoring
- Team Orientation
- Back-Up Behavior
- Adaptability
- Mutual Trust

**TEAM EFFECTIVENESS**

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

- ATC
- Airline Ops Centers