Enhancing Team Performance for Long-Duration Space Missions

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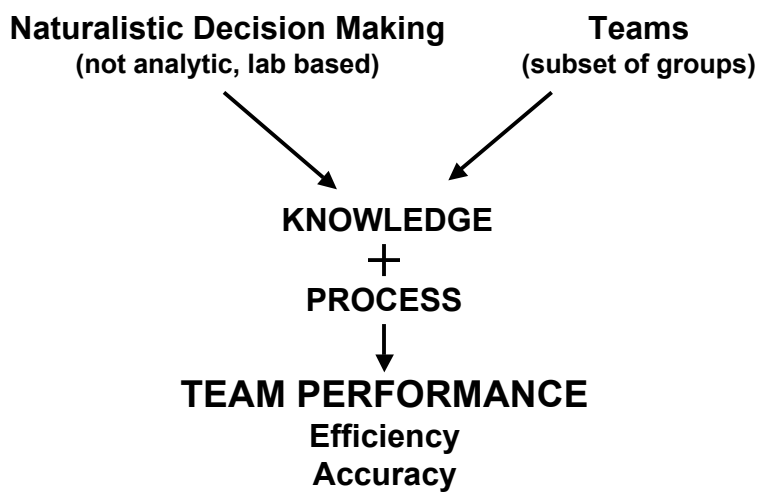
Exploration Missions: Unforgiving Isolated and Confined Environments, Stressors

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



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

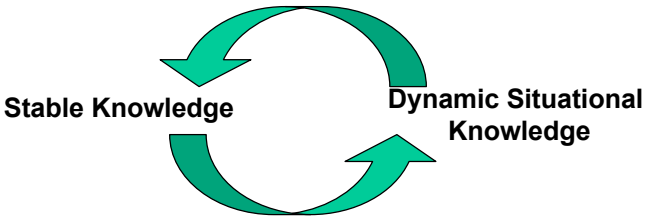
I. *Features of Effective Team Cognition*

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

I. *Features of Effective Team Cognition*

Shared Mental Models

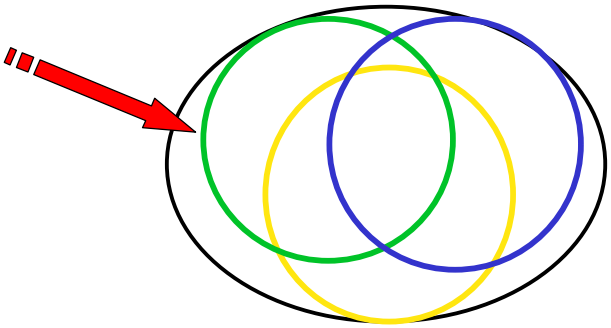


- ***Mental Models***
  - Understand, explain, predict
  - Models for
    - System
    - Tasks
    - Procedures - including roles & responsibilities
    - Teamwork - interaction and coordination processes
    - Individual team members

I. *Features of Effective Team Cognition*

Shared Mental Models

- ***How much overlap? Original view***

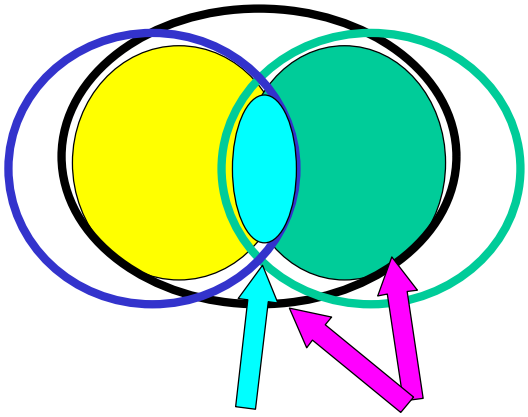


Goal = Maximize overlap

Features of Effective Team Cognition

Shared Mental Models

New View of "Shared" Knowledge



+ Shared *GOALS*

Shared = Common + Complementary

I. Features of Effective Team Cognition

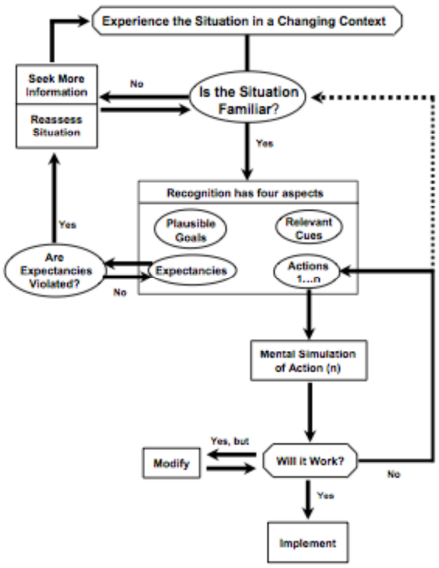
Collaborative Decision Making

- ***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

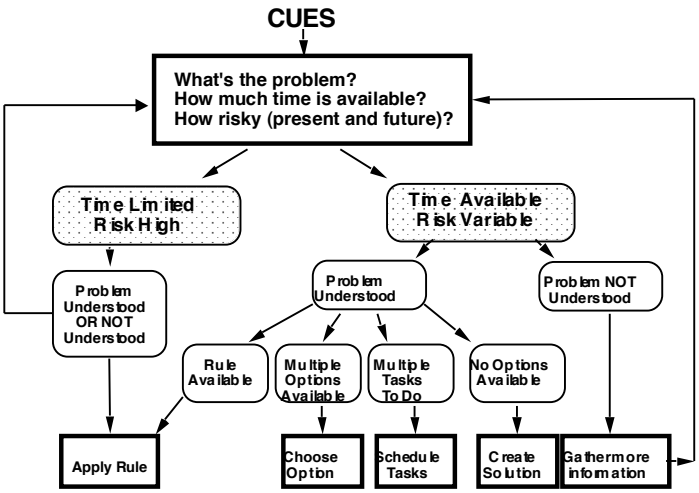
Collaborative Decision Making - NDM

- ***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



I. Features of Effective Team Cognition

Collaborative Decision Making

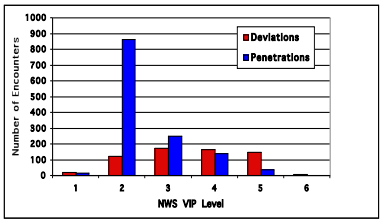
- ***Risk Assessment***
  - Implicit process - but evident in data
    - Monitoring - challenging study
    - MIT-LL study: pilots diverting around thunderstorms
  - Make explicit: low-fidelity sim study

Captain: "*Smell the rain. Smell it?*"

First officer: "*Yup. Got lightning in it too.*"

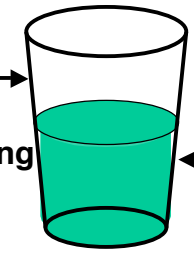
- ***"Managers pursue risky actions because they fail to perceive accurately the risks involved."***

(March & Shapira, 1987, p. 33)



(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

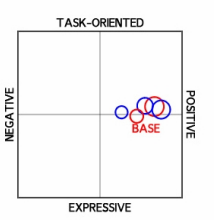
I. Features of Effective Team Cognition

Collaborative DM - Communication Processes

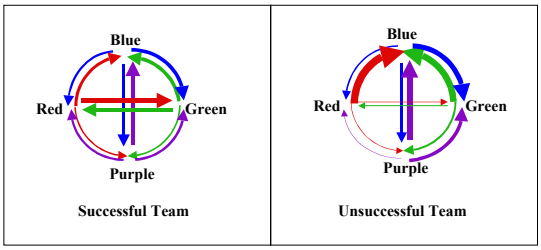
- ***Taskwork***
  - Share information - explicit (build shared sit model)
  - Closed loop
  - Efficient: Grice's maxims
- ***Teamwork***
  - Briefings
    - CDR's intent, strategies, plans, contingencies
    - Involve all crewmembers
  - Error correction (Monitoring/challenging)
    - Maintain positive crew climate - fix problem
  - Relational communication
    - Important to cohesion
  - INDIRECT techniques to assess
    - C.f. EXEMSI (Cazes, Rosnet, Bachelard, Le Scanff, Rivolier (1996)

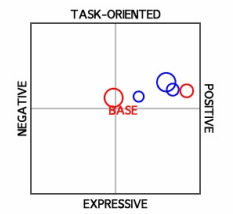
I. Features of Effective Team Cognition

Collaborative DM - Communication Processes

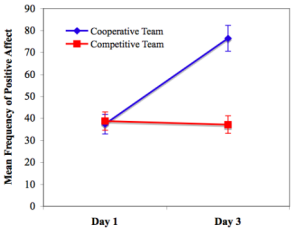


Unified Team (328)





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

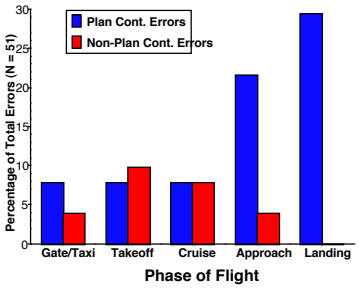


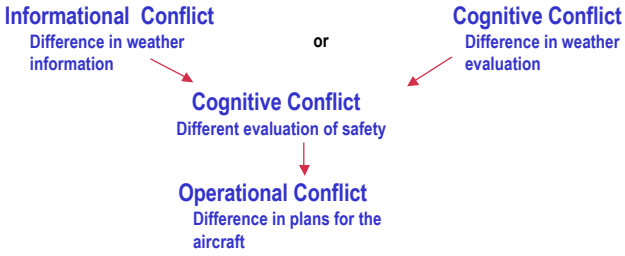
Table 2. Distribution of Error Types Across Original and Present Datasets

Error Category	% Total Errors	
Primary errors	1978-1990 37accidents 302 errors	1991-2000 14accidents 103 errors
Procedural - PR*	24.1	13.6
Tactical decision – TD	16.8	19.4
Aircraft handling – AH	15.2	11.6
Situation awareness – SA*	5.9	13.6
Systems operation – SO	4.6	7.8
Communication – CO	4.3	-
Resource management – RM*	3.6	17.5
Navigational – NV	1.9	-
Secondary errors		
Monitoring & challenging – MC	22.8	16.5

* $x < 0.025$

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

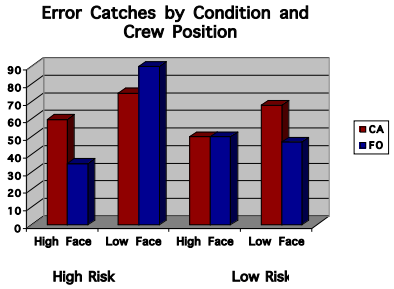


II. Threats to Effective Team Cognition
Individual stressors

- ***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

III. Supporting Effective Team Collaboration
TACT, TDT

- ***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

  (Cooke, Kiekel, Salas, Stout, Bowers, & Cannon-Bowers, 2003)

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

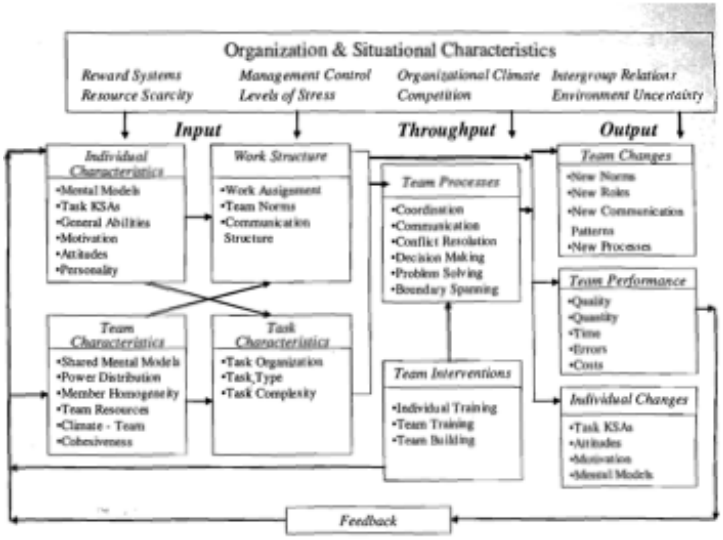


Figure 7.1 Team effectiveness framework adapted from (Tannenbaum, Beard and Salas, 1992)

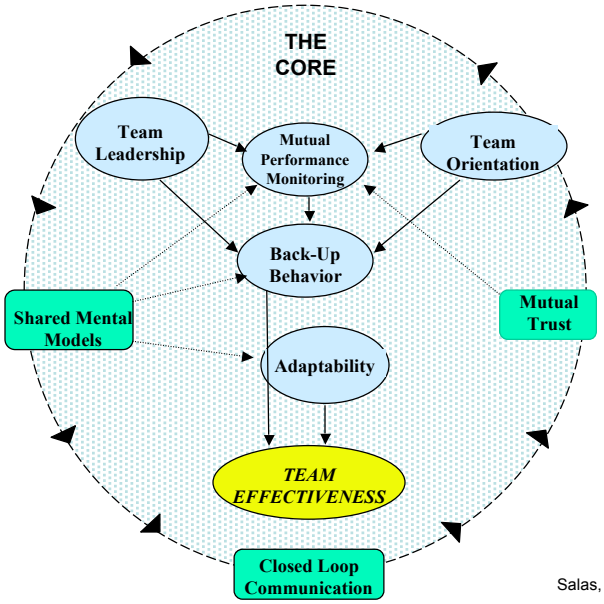
III. Supporting Effective Team Collaboration
Technology Supports

- ***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

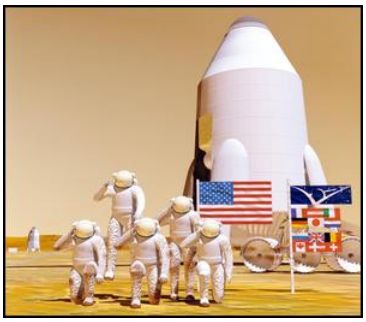
Graphical representation of high-level relationship between the 'Big Five' and coordination mechanisms



Salas, Sims, & Burke, 2006

Questions?

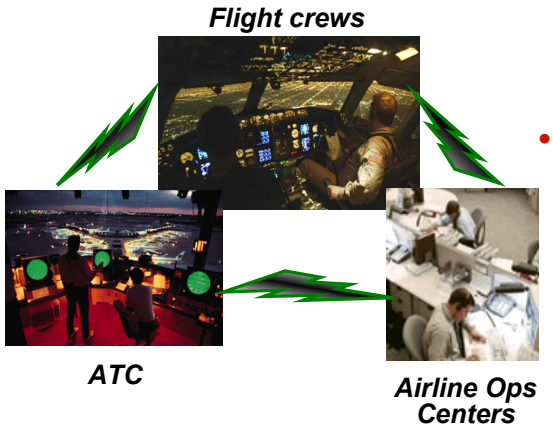
- *I look forward to your input*
- *Judith.Orasanu@nasa.gov*



We all THANK YOU!

Happy campers

Distributed Problem Solving in Aviation



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