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Analysis of Team Collaboration across Decision-Making Domains to Empirically Evaluate a Model of Team Collaboration

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Macrocognition

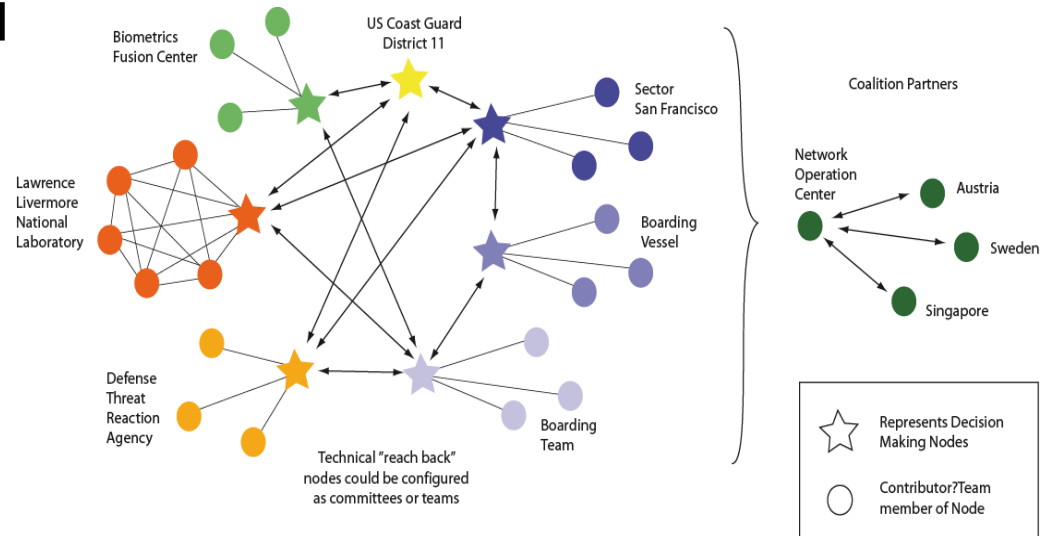
- **Mental activities that must be successfully accomplished to perform a task or achieve a goal (Klein, Ross, Moon, Klein, Hoffman, & Hollnagell, 2003).**
- **The internalized and externalized high-level mental processes employed by teams to create new knowledge during complex, one-of-a-kind problem solving.**
- **Functions are generally performed during collaborative team problem solving, where the emphasis is on building new knowledge.**
- **A complex, multi-level phenomenon that involves development, refinement, and maintenance of higher-order cognitive processes and emergent states (Burke, 2007).**
- **Cognitive processes employed by team members in unique, information-rich, time-compressed collaborative problem solving**
 - **Individual and team knowledge development**
 - **Shared problem conceptualization**
 - **Mental model development**
 - **Solution option generation**
 - **Detecting problems, developing and sharing situation awareness, generating options, using analogues, mentally simulating courses of action, planning and re-planning, maintaining vigilance, and assessing risk (Klein, 2001).**

Team Collaboration



Collaboration occurs “when a group of autonomous stakeholders of a problem domain engage in an interactive process, using shared rules, norms, and structures to act or decide on issues related to that domain” (Gray, 1998, p.11).

- Provides increased information processing capacity where more minds are enlisted to handle complex problems (Hocevar, Jansen, and Thomas, 2004).
- Team members provide several perspectives on an issue for generating, choosing, and implementing action plans.
- A collaborative approach also provides greater flexibility and innovation where human judgment and experience are leveraged (Hocevar, et al, 2004.)



Team Types



- **Teams who employ asynchronous or synchronous communications among distributed team members to bring their heterogeneous knowledge to bear to solve the problem.**
 - **Each team member plays a functionally distinct role and contributes specialized knowledge and expertise.**
 - **Problem-solving teams are often formed to deal with a rapidly emerging difficult situation where consequences for error are severe.**
 - **Ad hoc teams brought together in response to a critical situation that requires the expertise of a diverse group of experts.**
 - **Operate in complex socio-technical settings where the systems employed require technical expertise**
 - **Operate within organizational constraints where there are often conflicting goals**



Credit: Michael J Coppola



From Adm Cebrowski Network centric warfare



Dynamic Decision-Making Tasks

- **A series of decisions is needed, that is, the problem-solving event comprises many decisions to effectively deal with the problem as it unfolds, e.g., firefighters, air warfare decision-making, and maritime interdiction operations (MIO).**
- **Decisions are not independent because current decisions are constrained by earlier decisions, and, in turn constrain later ones.**
- **The problem state changes during the decision process both autonomously, and as a consequence of the decision maker's actions.**
- **Decisions are made in real time (Brehmer, 1992).**
 - **It is necessary for the operator to consider how the current decision will solve the immediate problem, as well as how it will impact future aspects of the overall problem-solving task.**
 - **It is not sufficient to make correct decisions, “in the correct order, they also need to be made at the correct moment in time” (Brehmer, 1992).**
 - **Dynamic decision making is inherently stressful in part because the decision maker cannot control when these critical decisions have to be made.**

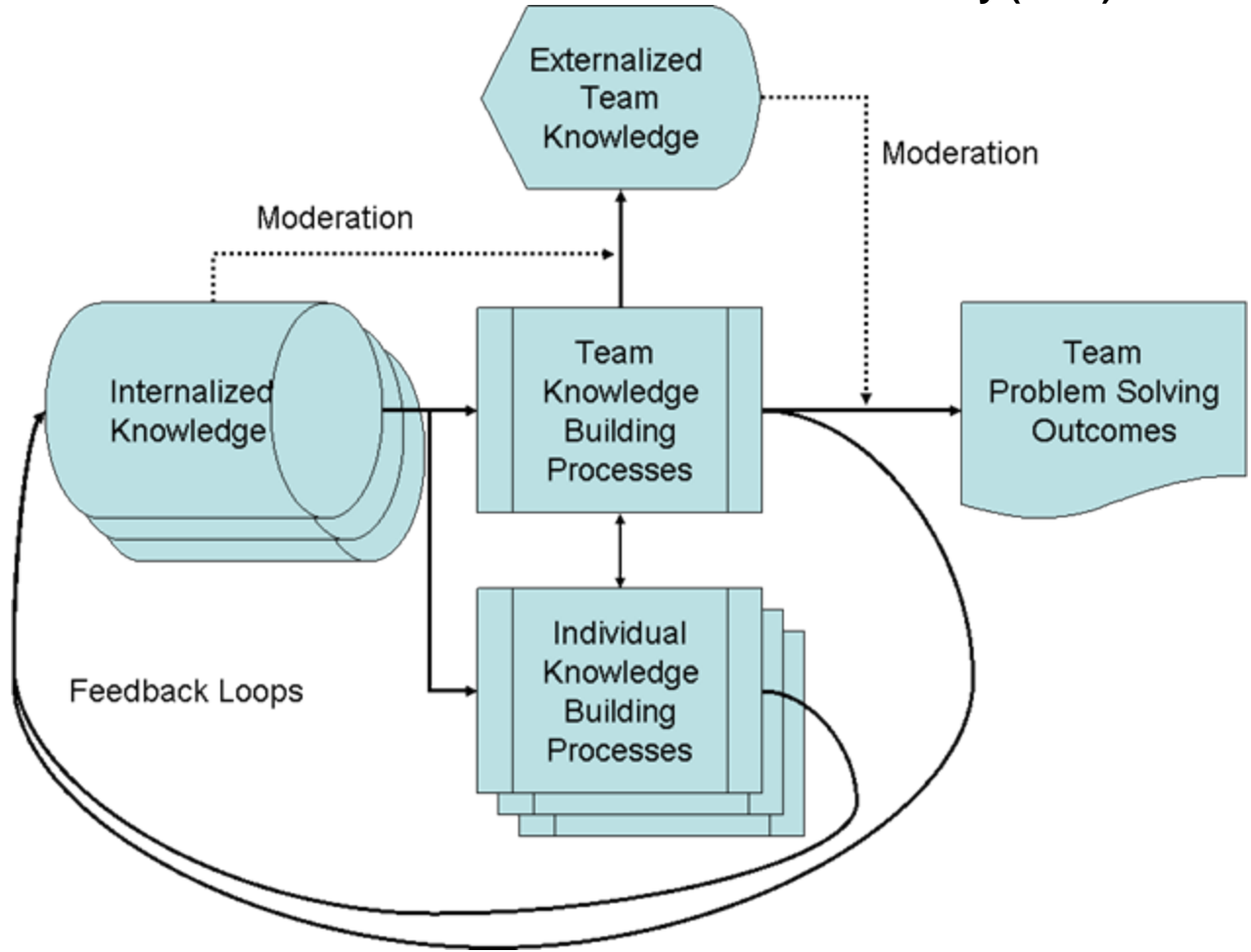


Dynamic Decision-Making Tasks (cont'd)

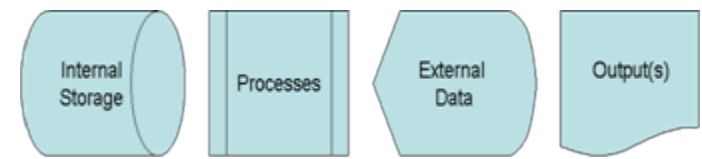
- **Decision making is viewed as a form of problem solving, where a person seeks a viable course of action.**
- **Dynamic decision making tasks are found across the spectrum of problem solving domains, including process control plants, patient management in hospitals, managing a business, and fighting a battle. All the tasks we examined were dynamic decision-making tasks, as opposed to planning tasks.**
- **In Klein's (1993) analysis of decision errors, he refers to (decision) process errors and (decision) outcome errors.**
- **Montgomery's approach (1983, 1989) views the function of decisions, as "to prepare for action and to make sure that actions are indeed carried out" (Brehmer, 1992, p.16).**
- **Implementing the decision often shapes both the problem as well as the cognitive process involved in decision making.**



Model of Team Collaboration (From Fiore, Smith-Jentsch, Salas, Warner, & Letsky (2008))



Legend



Note: Multiple overlapping symbols indicate representations for multiple team members.

Definitions of Macrocognitive Processes Included in Model of Team Collaboration

(From Fiore, Smith-Jentsch, Salas, Warner, & Letsky (2008))

Macrocognitive Process Categories	
Individual Knowledge Building	
Individual Information Gathering	Actions individuals engage in to add to their existing knowledge such as reading, asking questions, accessing displays, etc.
Individual Information Synthesis	Involves comparing relationships among information, context, and artifacts to develop actionable knowledge.
Knowledge Object Development	Involves creation of cognitive artifacts that represent actionable knowledge for the task.
Team Knowledge	
Team Information Exchange	Passing relevant information to the appropriate teammates at the appropriate times
Team Knowledge Sharing	Explanations and interpretations shared between team members or with the team as a whole
Team Solution Option Generation	Describes explanations and interpretations shared between team members or with the team as a whole
Team Evaluation and Negotiation of Alternatives	Describes clarifying and discussing the pros and cons of potential solution options
Team Process and Plan Regulation	Involves discussing or critiquing the team's knowledge building process or plan following feedback on its effectiveness.

Definitions of Macrocognitive Processes Included in Model of Team Collaboration

(From Fiore, Smith-Jentsch, Salas, Warner, & Letsky (2008))

Internalized Team Knowledge	
Team Knowledge Similarity	The degree to which differing roles understand one another (e.g., how well a land/sea vehicle specialist understands a humanitarian specialist), or how well the team members' understand the critical goals and locations of important resources (shared situation awareness).
Team Knowledge Resources	Team members' collective understanding of resources/ responsibilities associated with the task.
Inter-positional Knowledge	Accurate knowledge regarding position-specific roles, goals, responsibilities, access to information, constraints, and interdependencies with other team positions.
Individual Situational Awareness	Accurate awareness of moment to moment changes in the team's environment. The construct has been defined previously by Endsley (1995)
Externalized Team Knowledge	
Externalized Cue-Strategy Association	Describes the team's collective agreement as to their task strategies and the situational cues that modify those strategies (and how).
Pattern Recognition and Trend Analysis	Refers to the accuracy of the patterns or trends explicitly noted by members of a team that is either agreed upon or unchallenged by other team members.
Uncertainty Resolution	The degree to which a team has collectively agreed upon the status of problem variables (e.g., hostile/friendly).

Definitions of Macrocognitive Processes Included in Model of Team Collaboration

(From Fiore, Smith-Jentsch, Salas, Warner, & Letsky (2008))

Team Problem Solving Outcomes	
Quality of plan (problem solving solution)	Involves the degree to which the solution adopted by a problem solving team achieves a resolution to the problem (e.g., limit fatalities, limit destruction).
Efficiency of planning process	Amount of time it takes a problem solving team to arrive at a successful resolution to a problem.
Efficiency of plan execution	Quality of the plan (e.g., number of lives saved) divided by the amount of resources used to accomplish this and the amount of time the plan takes to unfold.

Method

- **Verbatim transcripts/chat logs were analyzed from an Air Force exercise and one real-world event where teams collaborated to solve a complex problem**
 - **Air Force Air Operations Center TRENCH: Dynamic planning and execution exercise involving time-sensitive targeting**
 - **North American Aerospace Defense Command (NORAD), on Sept. 11, 2001**
- **Transcripts included communications that occurred between all team members as well as with decision makers at the distributed sites.**
- **Team communications data were analyzed and coded using definitions of the macrocognitive processes in the model of team collaboration, developed by Fiore, Smith-Jentsch, Salas, Warner, & Letsky (2008).**
- **Coders practiced on a separate set of team communications and calibrated their coding after coding 200 lines.**
 - **Two coders reviewed their coding with one of the authors and discussed any differences in interpreting the definitions prior to coding the communications data to be analyzed.**
 - **Air Operations Center data: 2515 lines of code**
 - **NORAD data: 1517 lines of code**
 - **Each utterance was coded separately**

Percentage of Macrocognitive Processes used Across Decision-Making Domains

Code	Macrocognitive Process Categories	Percentage of Speech Turns	
Individual Knowledge Building		Air Ops Center	NORAD
IIG	Individual Information Gathering	16.66	29.37
IIS	Individual Information Synthesis	1.04	1.66
KOB	Knowledge Object Development	0.00	0.00
Team Knowledge Building			
TIE	Team Information Exchange	37.57	50.44
TKS	Team Knowledge Sharing	5.45	3.58
TSOG	Team Solution Option Generation	0.35	2.93
TENA	Team Evaluation and Negotiation of Alternatives	0.13	0.00
TPPR	Team Process and Plan Regulation	0.00	0.00
Internalized Team Knowledge			
ITK	Team Knowledge Similarity	0.03	0.00
TKR	Team Knowledge Resources	0.06	0.00
IK	Inter-positional Knowledge (3)	0.06	0.19
ISA	Individual Situational Awareness (1)	0.00	1.60
Externalized Team Knowledge			
ECSA	Externalized Cue-Strategy Association	0.13	0.06
PRTA	Pattern Recognition and Trend Analysis	0.11	0.06
	Uncertainty Resolution	0.00	0.12
Problem Solving Outcomes			
QOP	Quality of plan (problem solving solution)	0.00	0.00
EPP	Efficiency of planning process	0.00	0.00
EPE	Efficiency of plan execution	0.00	0.00
Decision to Take Action			
DTA: COA	To subordinate: issuing a course of action	4.72	1.21
DTA: RTA	Peer-to-peer request a team member take action	2.75	4.09

Problem Solving Includes Taking Actions

Examples of Decision to Take Action from NORAD Coding	Decisions
Your pilots should be loading and just make sure your pilots load up their mode 2 and mode 4.	COA
Give me a track number on that bomb -- that guy going by .	RTA
Give me an arrow, Bud. Scope 2, scope 1.	RTA
Just make sure its squawking.	RTA
On your mode 2, make sure that's standard and also make sure you're mode 4 is all loaded up as well.	COA
Turn him around and have him go look.	RTA
Can you help some of these people at tracking this bird?	RTA
And get all mode 3.	COA
Have them call for that.	RTA
If you don't see them, call right away. If you see it and they haven't hit it up, call that center.	COA
Tell them we need to know where Air Force One is.	COA

Chat log Entries Coded as Macrocognitive Processes in the Model of Team Collaboration

Individual Knowledge Building

IIG: Individual Information Gathering

- **What is the correct way to pass tasking to a predator to attack?**
- Do you know the local threat/ risk in (target location), and do you have imagery location of the locations

IIS: Individual Information Synthesis

- Senior Intelligence Duty Officer (SIDO), Reliable sources report probably radiological transload site at @LOCATION@
- **It is suspected that (Country #1) uses this location as a storage facility for spent fuel.**

KOD: Knowledge Object Development

- Code not used

Team Knowledge Building

TIE: Team Information Exchange

- **The actual snatch and grab would be possibility for SOF but we would need the intelligence assist.**
- ISRC: for your information, @LOCATION@ is now SOF mission; reconnaissance a/c #1 to provide over watch, SOF is in contact with a/c now.

TKS: Team Knowledge Sharing

- **Self defense applies for hostile acts from (Country #3) fighters in (Country # 2) or (Country #4) airspace**
- Enemy forces that employ ordnance, Electronic Attack (EA), or force control systems (achieve a radar lock) against friendly forces have committed a hostile act.

TSOG: Team Solution Option Generation

- **Awaiting radiological impact assessment on watershed if strike building. Second option in work is deny (destroy) local roads to prevent access in/out.**
- If we crater the runway and taxiways, we may be able to effectively stop the target.
- To shorten timeline for tactical tomahawk we can launch to loiter

Chat log Entries Coded as Macrocognitive Processes in the Model of Team Collaboration

TENA: Team Evaluation and Negotiation of Alternatives <ul style="list-style-type: none">▪ Target Duty Officer (TDO): Just throwing this out there, but if you target the roadways, is there a chance you could spook them and they might fire off their missiles and run?
TPPR: Team Process and Plan Regulation <ul style="list-style-type: none">▪ Not used
Internalized Team Knowledge
TKS: Team Knowledge Similarity <ul style="list-style-type: none">▪ SIMISM. C2WSPTT always expends all weapons on attack▪ He wouldn't request return to base he'd tell you he is returning to base
TKR: Team Knowledge Resources <ul style="list-style-type: none">▪ <u>Interpositional Knowledge (IK)</u>: I remember sketchy authentication▪ <u>Individual situation awareness (ISA)</u>: a/c #2 is out of position, looks like other strike assets quicker
Externalized Team Knowledge
ECSA: Externalized Cue-strategy Association <ul style="list-style-type: none">▪ The DEC Chief stated that if there is an erect launcher in a JSOA his "ROE" is to kill it ASAP and if there is time to deconflict with the teams▪ He mentioned TLAMs wouldn't be deconflicted either, but I dispute that logic. First, we wouldn't use a TLAM shot to kill a launcher I don't think. Unless it was a last resort.▪ Can get SOF Team to location as additional resource if we elect to monitor the site for any potential leadership meetings that may occur later given that location is used for meetings and (target) is there now.

Chat log Entries Coded as Macrocognitive Processes in the Model of Team Collaboration

PRTA: Pattern Recognition and Trend Analysis

▪ **Co, TDO, looks like ***** may be similar to our first target with regards to unknown presence of Radiological containers in facility. We would look at interdiction for containment to prevent travel to/fm that site, your thoughts on best plan/option**

UR: Uncertainty Resolution

▪ **TLAMs most definitely have to be de-conflicted even for over flight of the Joint Special Operations Area (JSOA)-unless direct otherwise by the Joint Force Commander (JFC)**

Team Problem Solving Outcomes

QOP: Quality of Plan

• Not used

EPP: Efficiency of Planning Process

• Not used

EPE: Efficiency of Plan Execution

• Not used



New Coding Category: Decision to Take Action

A new macrocognitive process emerged during the coding process:

- **Deciding to take action is viewed as both a macrocognitive *process* and a *product* of team collaboration.**
- **Many critical tasks include taking action in addition to developing new knowledge and agreeing on a final solution.**
 - **Various actions are taken as part of information gathering process (e.g., MIOs, air warfare, firefighters, NORAD-FAA, AOC, etc.).**
 - **Dynamic decision-making tasks entail a series of decisions as part and parcel of problem solving.**
 - **Many tasks involve an interleaving of knowledge building, decision making and taking action in order to accomplish the mission.**
- **A constant interplay exists between sharing information to develop new knowledge and maintain situation awareness and then executing, or implementing actions, followed by monitoring and building new knowledge on the unfolding situation.**
 - **Execution of the mission, would come to a screeching halt without this continual, iterative cycle of developing knowledge of the situation and responding to the current situation by taking various actions that move the problem along.**