Collaborative Critical Thinking

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Pacific Science & Engineering

Collaboration and Knowledge Management Workshop

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# Collaborative Critical Thinking

Collaboration and Knowledge Management (CKM) Workshop, 14-16 Jan 2003, College Park, MD. U.S. Government or Federal Rights License

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Agenda

- Motivation & Objectives
- Collaborative Critical Thinking (CCT) defined
- Conceptual Model
- Experiments
- Planned CCT Technology and Training Products
Agenda

• Motivation & Objectives
  • Collaborative Critical Thinking (CCT) defined
  • Conceptual Model
  • Experiments
  • Planned CCT Technology and Training Products
Motivation & Objectives

- **Goal:** effective collaboration
  - Collaboration at a distance—enabled by network connectivity—is central to 21st century Command and Control
- Collaboration **technology capabilities** have outpaced understanding of collaboration
- Need **insight into the cognitive processes** involved in effective collaborative in order to best design and use the technology
- Our focus: **collaborative critical thinking.**

- **Our objectives:**
  - Define,
  - Measure, and
  - Strengthen CCT w/ tools and training
Agenda

- Motivation & Objectives
- Collaborative Critical Thinking (CCT) defined
  - Conceptual Model
  - Experiments
  - Planned CCT Technology and Training Products
Examples

- **Template**
  - Team Member A: **States assessment**
  - Team Member B: **Proposes alternative assessment**

- **Transcript:**
  - Mike: **Study Thomas's use of the US Calvery with repeating firearms** in the battle of Nashville. Especially the follow-up where Hood's army was totally destroyed as a fighting force.
  - Robert: As for the Battle of Nashville, a much better point is **don't let your commander become a opium addict**. Much of what was left of the Army of Tennessee had already been squandered on the useless assualts at Franklin. While Thomas did a commendable job of defeating the remains, the issue was hardly in doubt.

- **Source:** sci.military newsgroup
Examples

- Template
  - Team Member A: **Monitors for risk**
  - Team Member B: **Identifies source of risk**
  - Team Member A: **Concurs**

- Transcript:
  - Harriet: *It looks like one subject was sort of pulling it up there...*
  - Sam: Yeah, there's one slow subject, uh or two at the end.
  - Keith: **Well you could have a selection effect.** In that ...
  - Sam: ... in the examples...
  - Keith: **Slower subjects in the example condition, because they fail.**
  - Sam: That's correct, uh yeah.

- Source: Chris Schunn, Ph.D., LRDC
Examples

- **Template**
  - Team Member A: **Monitors for risk**
  - Team Member B: **Identifies source of risk**
  - Team Member B: **Plans investigation of source of risk**
  - Team Member A: **Prompts for contingency plan**
  - Team Member B: **Proposes contingency plan**

- **Transcript:**
  - Mike: We need to redirect our friendlies to account for **SAM A34’s relocation**.
  - Gavan: Ok. **I thought this SAM was fortified, stationary.**
  - Mike: Negative. ComInt has just reported that the SAM is moving.
  - Gavan: I see it. **Didn’t ELINT and IMINT report no movement** and no support? **Doesn’t COMMINT** get their information from the other two?
  - Mike: That’s my understanding, but I will confirm that.
  - Gavan: So, **we should check back to make certain these reports are correct**. Why don’t you check back with IMINT and I’ll check back with ELINT to verify this information. We still have a bit of time. Ask them how conclusive their information is. How did they decide this SAM would not move?
  - Mike: **Shouldn’t we decide on a time to abort the mission** or at least to make a final call?
  - Gavan: Yes. Probably the safest thing to do would be to **cancel the mission if we aren’t certain about that SAM**. We can’t reroute. Let’s huddle no later than 0500 and make a final call no later than 0600.

- **Source:** Aptima intelligence scenario
What is Collaborative Critical Thinking?

- Collaborative Critical Thinking (CCT) is an interactive process for evaluating and refining assessments, plans, and teamwork.
Characteristics of Collaborative Critical Thinking

- **Interactive** – CCT is collaborative
- **Evaluative** – CCT involves:
  - Monitoring & perception for risk or uncertainty
  - Assessing the priority of addressing this risk (given other tasks)
  - Identifying source(s) of risk or uncertainty (assumptions, gaps, conflicts)
- **Productive** – Leads to action that bear on:
  - problem assessment … reframes the problem
  - problem solutions
    - Gathering information by probing, testing, waiting
    - Eliminating the problem (e.g., an enemy outpost)
    - Developing contingency plans
  - team state, process, and structure
  - team CCT skills
- **Distributed** – CCT may be conducted by teams distributed over space or time.
  Critical factors:
  - Conduits for communication and collaboration
  - Transactive memory (of who said what, did what, can do what)
  - Public representations of problem state and (transaction) history
- **Addresses ill-defined problems** – No agreed upon method or answer
Agenda

- Motivation & Objectives
- Collaborative Critical Thinking (CCT) defined

**Conceptual Model**
- Experiments
- Planned CCT Technology and Training Products
Conceptual Model

**Factors Generating Need to Collaborate**
- Nature of mission
- Division of resources & responsibilities
- Distribution of expertise

**Factors Affecting Ability to Collaborate**
- Technology Factors
- Process/Skill Factors
- Team Composition Factors

**Collaborative Critical Thinking**
- Tool
- Training

**Goals of Collaboration**

**Products of Collaboration**
- Solutions and plans
- Shared knowledge and awareness

**Effects of Collaboration on Mission Performance**
- MOEs

**Importance of Collaboration**

**Success of Collaboration**
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- Motivation & Objectives
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- Conceptual Model

**Experiments**
- Planned CCT Technology and Training Products
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Success of Collaboration

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Collaborative Critical Thinking

Tool

Training
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Conceptual Model

Variables we manipulate
Success of Collaboration

Factors of Collaboration

• Solutions and plans
• Shared knowledge and awareness

Effects of Collaboration on Mission Performance

• MOEs

Importance of Collaboration

Factors Generating Need to Collaborate

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Factors Affecting Ability to Collaborate

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• Process/Skill Factors
• Team Composition Factors

Products of Collaboration

• Solutions and plans
• Shared knowledge and awareness

Measures we take

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University of South Florida

Department of the Navy

Science & Technology
Factors we Control

Factors Generating Need to Collaborate
- Nature of mission
- Division of resources & responsibilities
- Distribution of expertise

Factors Affecting Ability to Collaborate
- Technology Factors
- Process/Skill Factors
- Team Composition Factors

Products of Collaboration
- Solutions and plans
- Shared knowledge and awareness

Effects of Collaboration on Mission Performance
- MOEs

Importance of Collaboration

Goals of Collaboration

Collaborative Critical Thinking
Factors Generating **Need to Collaborate**

- Nature of mission
- Division of resources & responsibilities
- Distribution of expertise

- Mission is *complex* and *time sensitive*
- Resources & responsibilities are *divided* among team members
- Expertise is *distributed* between team members
Variables We Manipulate

Factors Generating Need to Collaborate
- Nature of mission
- Division of resources & responsibilities
- Distribution of expertise

Factors Affecting Ability to Collaborate
- Technology Factors
- Process/Skill Factors
- Team Composition Factors

Products of Collaboration
- Solutions and plans
- Shared knowledge and awareness

Effects of Collaboration on Mission Performance
- MOEs

Importance of Collaboration

Success of Collaboration

Goals of Collaboration

Factors Affecting Mission Performance
### Factors Affecting **Ability** to Collaborate

- **Technology Factors**
- **Process/Skill Factors**
- **Team Composition Factors**

<table>
<thead>
<tr>
<th>Collaboration technology measures</th>
<th>Reach: Team connectivity</th>
<th>Interconnectivity of team members to each other (“Communities of interest”)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reach: Information connectivity</td>
<td>Interconnectivity of team members to information sources (“Information access”)</td>
<td></td>
</tr>
<tr>
<td>Reach: Translation</td>
<td>Degree to which tool supports translation between representations, domains, and languages</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Richness: Structured problem representation</th>
<th>Degree to which the tool provides structured representations of the problem at hand</th>
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</thead>
<tbody>
<tr>
<td>Richness: Deconfliction</td>
<td>Degree to which the tool supports coordination of activities via a shared workspace</td>
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</table>
### Variables We Manipulate – Training

#### Factors Affecting Ability to Collaborate
- Technology Factors
- **Process/Skill Factors**
- Team Composition Factors

<table>
<thead>
<tr>
<th>CCT process measures</th>
<th>Planning for TC²T</th>
<th>Collaboration communications (e.g., paraphrasing others, explicit statement of monitoring plans &amp; criteria) during planning stage.</th>
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</thead>
<tbody>
<tr>
<td>Monitoring</td>
<td>Number of critiques initiated concerning high priority issues</td>
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<tr>
<td>Diagnosis</td>
<td>Number of gaps, conflicts, and untested assumptions identified</td>
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<tr>
<td>Action</td>
<td>Instances of probing own resources for data, testing enemy or environment for data, intentionally waiting out problem</td>
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</table>
**Factors Generating Need to Collaborate**
- Nature of mission
- Division of resources & responsibilities
- Distribution of expertise

**Factors Affecting Ability to Collaborate**
- Technology Factors
- Process/Skill Factors
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**Importance of Collaboration**

**Goals of Collaboration**

**Effects of Collaboration on Mission Performance**
- MOEs

**Products of Collaboration**
- Solutions and plans
- Shared knowledge and awareness

**Tools and Training**

**Collaborative Critical Thinking**
# Measures We Take

## Products of Collaboration

- Solutions and plans
- **Shared knowledge and awareness**

<table>
<thead>
<tr>
<th>Shared awareness measures</th>
<th>Description</th>
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<tbody>
<tr>
<td>Shared situation awareness</td>
<td>Degree to which team members share memory for current location of objects in the tactical picture</td>
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<tr>
<td>Shared predictions of future situation</td>
<td>Degree to which team members share predictions of the location of objects in the tactical picture</td>
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<tr>
<td>Shared situation assessment</td>
<td>Degree to which team members share assessments of the intent of entities of operational interest</td>
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<tr>
<td>Mutual awareness of goals</td>
<td>Degree to which team members express shared goals</td>
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<tr>
<td>Mutual awareness of information needs</td>
<td>Degree to which team members anticipate the information needs of teammates</td>
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<tr>
<td>Mutual awareness of next action(s)</td>
<td>Degree to which team members anticipate the actions of teammates</td>
</tr>
<tr>
<td>Mutual awareness of workload</td>
<td>Accuracy with which team members estimate the subjective workload of teammates</td>
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</table>
Measures We Take

Factors Generating Need to Collaborate
- Nature of mission
- Division of resources & responsibilities
- Distribution of expertise

Factors Affecting Ability to Collaborate
- Technology Factors
- Process/Skill Factors
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Effects of Collaboration on Mission Performance
- MOEs

Goals of Collaboration

Collaborative Critical Thinking
- Tool
- Training

Importance of Collaboration

Success of Collaboration
# Measures We Take

## Effects of Collaboration on Mission Performance

### MOEs

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<thead>
<tr>
<th>MOEs</th>
<th>Description</th>
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<tr>
<td>Synchronization: Allocation</td>
<td>Proportion of tasks executed without conflicts in resource allocation</td>
</tr>
<tr>
<td>Synchronization: Execution</td>
<td>Proportion of tasks requiring coordination that are successfully executed</td>
</tr>
<tr>
<td>Synchronization: Precision</td>
<td>Lag in readiness for execution of synchronized events between first and last operator ready to act.</td>
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<tr>
<td>Effects: Enemy losses</td>
<td>Proportion of targets or threats destroyed</td>
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<tr>
<td>Effects: Friendly losses</td>
<td>Proportion of friendly forces destroyed or lost</td>
</tr>
<tr>
<td>Effects: Delay in enemy ops</td>
<td>Latency in enemy maneuvers or actions (e.g., bombing targets) due to friendly actions</td>
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<tr>
<td>Effects: Team process</td>
<td>Average delay in task execution relative to optimal task execution schedule</td>
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Draft Experiment

• Hypotheses
  • H1: CCT tools and/or training improve shared awareness of uncertainty and risk. (Ability/Process)
  • H2: CCT tools and/or training increase the incidence of CCT behaviors. (Ability/Process)
  • H3: CCT tools and/or training improve the team plans. (Products)
  • H4: CCT tools and training improve mission execution and outcomes. (Effects)
• Materials: Military scenario in which
  • some aspects of the situation are well defined, others are not.
  • some risks can be reduced by information gathering or probing
  • some risks cannot be reduced and require contingency plans
• Testbed: Distributed Dynamic Decision-making (DDD) Simulation
  • Team research testbed
  • Collaboration measurement capability
  • Developed at U.Conn, freely available, used at 25 labs
• Subjects: ROTC and undergraduate students
• Method:
  • Pretest domain knowledge & critical thinking ability
  • Scenario (re)planning phase ↔ execution phase
  • Real time measures of CCT
  • Posttest measures of CCT
• Analysis: Multi level modeling supports analysis of group, individual, their interaction (individual on this team), and error for group and individual
Agenda

- Motivation & Objectives
- Collaborative Critical Thinking (CCT) defined
- Conceptual Model
- Experiments

- Planned CCT Technology and Training Products
Tool Development

• Hypothesis:
  • Team awareness of deficits in shared awareness (regarding, e.g., risk involved and predicted outcomes) enable teams to improve awareness and mission effects.
  • Tool will help the team evaluate its state and identify opportunities for critical thinking
    • Each team member will answer questions about the risk involved and the predicted outcomes
    • These values will be combined to calculate the team’s mutual awareness of risk and predicted outcomes
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<th>Is target localized?</th>
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<th>2</th>
<th>3</th>
<th>4</th>
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<td>Is target identified?</td>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
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<td>Are munitions correct for given target?</td>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
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<td>Is airspace deconflicted?</td>
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<td>2</td>
<td>3</td>
<td>4</td>
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<td>What is the probability that we will kill?</td>
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<td>3</td>
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<td>What is the probability that we will lose one of our assets?</td>
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<td>2</td>
<td>3</td>
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Mutual Awareness of Risk:

<table>
<thead>
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<th>Mutual Awareness of predicted outcomes:</th>
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<tr>
<td>Bad</td>
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Training Development

• Hypothesis: CCT training will help teams to:
  • Identify the triggers in the situation that require CCT
  • Weigh benefits of engaging in CCT across all priorities
  • Exercise their CCT faculties to improve plans

• Possible training topics:
  • Domain-independent CCT
    • Training in devil’s advocate strategies
    • Training in appropriate situation for CCT (e.g., need for high quality, with relatively little time constraints)
  • Domain-specific CCT – Train to identify and critically evaluate problem. E.g., determine why there are problems localizing enemy. Is it caused by:
    • deliberate deception by enemy
    • Reliability of source
    • Stale data
## Project Timeline

### 28 August 2002 through 27 August 2004

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- **Briefings to the clients**
- **Progress reports (quarterly)**

**Schedule:**
- 28 August 2002 through 27 August 2004
Background Materials
References


References

Project Summary

• Title: Collaborative Critical Thinking
• Jared Freeman, Ph.D., P.I.
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• Objectives
  • A fundamental goal of military is to ensure that C2 organizations operate decisively and synchronously in highly uncertain and dynamic settings. Individuals succeed in these settings by thinking critically, that is by critiquing their understanding of the situation at hand, refining their knowledge, and adapting their decision making and planning to the problems at hand. This project proposes that individual team members collaborate in their application of critical thinking in a process called “team critical thinking”. The project will develop the concept of collaborative critical thinking within C2 teams from three research threads concerning: individual critical thinking, team process and architecture, and human performance in information age warfare. These research threads will be woven together to create a theory, validated measures, and tools and techniques that help understand and support team critical thinking. The team collaboration and critical thinking theory will help explain how teams critique their understanding of the current situation. It will illustrate how teams incrementally refine their shared assessments and plans or radically revise their beliefs and conceptual frameworks. In addition, the theory will help explain how teams turn their critical faculties on themselves to assess and adapt the fit of team processes and team structure to the situation at hand.
  • Based on these measures, training, tools, procedures and team architectures that improve team critical thinking will be developed. The end product will be a solid foundation in theory, measurement, and practical support for improving C2 teams as they confront the challenging and varied missions of the 21st century.
• Research Questions
  • What are the behavioral markers of collaborative critical thinking?
  • How can CCT behaviors and their effects be reliably measured in a semi- or fully automated fashion?
  • Can we promote CCT behaviors with training and job aids?
• Project Status
  • Two theoretical frameworks have been developed, one concerning collaboration generally, and the other addressing the role of CCT within collaboration.
  • A set of measures has been drafted that addresses several aspects of collaboration and CCT.
  • Design discussions are underway for experiments, tools, and training