Human Systems Integration: Issues and Challenges

Lindsley Boiney, PhD
The MITRE Corporation
(781) 271-2640
lboiney@mitre.org

MIT IAP Symposium
January 25, 2006
Research Problem

- Network Centric Operations
- Greater complexity, increased reliance on teams
- Human decision making processes remain difficult, time-consuming
- Effective collaboration takes more than technology...
Key Focus: Time-Sensitive Targeting

0 Time-Sensitive Targeting (TST) cell within an Air Operations Center
- Team member roles such as Cell Chief, ISR, Intelligence, Weapons
- Joint membership across services (may share resources)
- Geographically distributed
- Time pressure, uncertainty

0 Sample Tasks
- Interpret intelligence reports, rules of engagement
- Develop sensor plan to find and identify targets
- Evaluate threats (should pop-up target supplant planned target?)
- Determine appropriate weapon to deploy
- Deconflict with other services
Collaboration: Challenges for Data Collection, Measurement & Analysis

Data Collection Methodology
- Ethnographic Observation
- Operator Interviews
- Chat Logs

Goal: Study Human Teams with Technologies in Rich Environment
Capturing Collaboration Process/Challenges: Leveraging Multiple Data Types

<table>
<thead>
<tr>
<th>Desired data characteristics</th>
<th>Observation</th>
<th>Interviews</th>
<th>Chat logs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short Latency</td>
<td>G</td>
<td>Y</td>
<td>G</td>
</tr>
<tr>
<td>Objectivity</td>
<td>Y</td>
<td>R</td>
<td>G</td>
</tr>
<tr>
<td>Modality completeness</td>
<td>G</td>
<td>Y</td>
<td>R</td>
</tr>
<tr>
<td>Thread completeness</td>
<td>R</td>
<td>Y</td>
<td>G</td>
</tr>
<tr>
<td>Contextualization</td>
<td>Y</td>
<td>G</td>
<td>R</td>
</tr>
<tr>
<td>Social cue capture</td>
<td>G</td>
<td>R</td>
<td>Y</td>
</tr>
</tbody>
</table>

Key: Green = usually very good  
Yellow = fair or varies widely  
Red = usually poor

Definitions:
Latency = temporal delay between the data collected and actual event (the smaller the better)
Objectivity = lack of bias or subjective filter between data and data source (relates to validity)
Modality completeness = ability to capture all modalities of inter-operator communications (face to face, audio, phone)
Thread completeness = ability to capture complete event/topic threads involving multiple operators, different locations
Contextualization = ability to situate data within surrounding context, reflect what was going on “in their heads”
Social cues = ability to capture human-to-human interactions reflecting emotions, social hierarchy, and other social cues
Observation Highlights from Time-Sensitive Command & Control Events

Role of Humans in CSCW

– validate information, and determine where to get more if needed
– engage in collaborative sensemaking – handling ambiguous or conflicting information
– establish trust and credibility with one another
– maintain sufficient team awareness to enable effective coordination, even when not co-located
– judge who should – and should not – receive information, balancing the need for sharing against the danger of cognitive overload
– select appropriate communication modalities for sharing information of varying importance, time-sensitivity, and intended audience
– cue other team members to important information, emerging events, or changing priorities.

Teams Manage More Than Information
Attention Management: “Where do I focus my attention?”

- **Operator juggled 8+ chat windows on right screen alone:**
  - Hears “ping” for an incoming chat message, “But which room is it in?”
  - Adaptation: highlights most recent message in each window; new messages appear unhighlighted, easy to spot (but must repeat…)

- **Self-organize to cue others:**
  - To returning TST Chief:
  - “You missed lots of chat on…” (indicates target and chat room)

Technology could better support human focus
Information Sharing: “Who else should see this?”

- Chief audio chats regarding leadership target
  - “Why are you working it? **Stop – it’s a misdirect.** Target is ‘in the background’… Don’t work it until it’s pushed to you.”

- Adaptation to avoid misdirecting others
  - TST Chief’s left screen displays target information on AOC data wall
  - Until sure of ID, he enters some targets as **hidden rows**

More information sharing isn’t always desired
Managing Relationships for Speed of Command

Teams of Teams
- In one scenario, Air and Land Component Commanders coordination key
- TST Chief proactively monitored LCC’s indicator on stoplight chart and communicated with them even when no action needed. Reported wanting to “get them energized,” ensure buy-in and coordination “before it’s a TST”

Challenge increases if crossing organizational boundaries
COLLABORATION MODEL (ongoing)

Communication
- of what?
- with whom?
- by what means?
- when?

Technology

Share knowledge, perspective:

Social, cultural, political:
- develop trust, credibility, accountability, buy-in

Develop shared SA, frame of reference

Convince, negotiate, reach consensus

Individual or Team

Attention Management

Uncertainty Management

Information Management

Situation Awareness
- Perception SA Level 1
- Sense making SA Level 2
- Projection SA Level 3

Decision Making:
- Response Selection

Monitor Environment, Response Execution

Problem? Adapt

Share the work:

Social, cultural, political: align priorities, goals, authority

Determine member roles, tasks, and coordination

Give process feedback

Maintain team awareness

Cue others

Team formation, reformation

Source: Lindsley Boiney
BACKUPS
Research Goals

- Understand “human agency” to enable complementarity between humans and information technology
- More formally and explicitly document collaboration processes, functions
- Understand human-system interactions in context
- Capture human adaptations, emergent behavior
  - can reveal unmet needs for effective collaboration in complex environments

“All futurists seem continuously anxious to replace humans… In general, it will be better to pursue not substitution but complementarity… [which] requires seeing the differences between information-processing agents and human agency.”

Research Questions

- What kinds of functions do humans perform in these collaborative environments?
- Why are the tasks so challenging?
- How they are currently done, and how to better support through improved technology and processes?
- Where does technology support or inadvertently hinder decision making, and why?
- Do available technologies work together in a complementary fashion, or are they difficult to use in combination?
- **Methodology question**: how to study the *multiple* tools and technologies that operator teams use to inform their judgments, in realistically “messy” contexts, given restrictions on data collection?
Joint Experiment in 2004

- Situation Awareness displays (map based)
- Target Coordination tools (“stoplight” sign-off)
- Instant Messaging tools
- Role-specific tools (e.g., weapon target pairing)
Example of 2 minutes with Cell Chief:
0 He **text** chats with an individual regarding a possible leadership target
0 **Audio** chats with another, asks why they’re working a target
0 Starts another **audio** conversation
0 Gets a **text** chat message requesting *chat in private (agrees)*
0 Starts another private **text** chat about priorities ("Is this urgent?")
0 **Audio** chats to entire TST team ("There are two actions heading our way, take a look.")
0 At the moment, he has his 8 regular chat room windows, plus 3 private text chats going, then audio chat comes in for him…
0 Initiates a follow-up **audio** chat to another individual. Gets no reply, so **text** chats: "Call me *on the headset or visit me*…"

This is *in addition to* target coordination application, emails, face-to-face conversations, public announcements, wall displays…
Combining All Three

- Look for overlap on content
- Fill “shortcomings” of one data source with the other(s)
- Do different data sources reinforce or contradict one another?
- Look for systematic, repeated issues
What to look for?

The lists below show the data source (e.g. chat logs, direct observations, and interviews), followed by useful information that can be obtained from that data source for analyzing time-sensitive collaboration. Ultimately, information from chat, observations, and interviews should be combined to provide a detailed understanding of the collaborative process that occurred.

1. Chat logs
   - Repeated requests for same information
   - Mention of conflicting information (sources? context? result?)
   - Mention of accuracy or latency of information or trust of info
   - Instances when someone wants less information
   - Using chat as a workaround for other failed systems
   - Coordination on tasks, priorities (you do this, you should not do that, we need to do this before that)
   - Discussions about who’s where, who’s busy, etc (team awareness)
   - Disagreements or effort to convince another (note issue, context, participants)
   - Whether/how people communicate identity (name, rank, position, service)
   - Discussions about trust within team, ability to rely on one another
   - Directions to use other medium (“call me”, “I’m coming over”, “get me so-and-so”)
     - due to judgment that other medium is more appropriate or effective or efficient for some reason?
     - due to technical problems?
   - Expressions of emotion
     - swearing, all caps, exclamation points...suggesting frustration or confusion
     - examples of humor or friendliness

Chat logs
What to look for?

(Chat logs, continued)

• Instances when one directs another to appropriate source, person (“you want to talk to Lt B”)
• Discussions about required format of information
• Any instances of inappropriate information sharing
  – someone clearly needed it but didn’t get it (try to determine why)
  – someone was misdirected or overloaded by it (went to wrong system or person)
  – wrong information sent
• Instances when request for info goes unanswered, or is obviously late (“sorry, we JUST got that information!”)
• Instances of info shopping (“does anyone know where I can find…who handles…how I go about…”)
• Mention of avoiding a system or tool, or distrusting its information
• Discussions about which chat room to use for what purpose
• Inappropriate use of a chat room
  – reprimands for using a room for wrong purpose, or for lurking
  – Reprimands for cross-posting or spamming
• Comments about goals, rules of engagement (ROEs)
• Comments about a scenario suggesting a challenging component
• Comments relating to time-pressure or stress or physical realities (heat, noise, etc.)
• Number of participants overall and per room, % active participants versus lurkers per room
• Number of chat rooms initially established, # chat rooms created during the event/conflict
• Percentage of joins and leaves per room
• Percentage of CIP (chat in private) requests per room
What to look for?

2. Observation

- Document their physical environment: how many screens; how many applications on each screen (and which ones); their use of phone or headphones; their use of wall displays; papers on their desk that they refer to; any swapping or maximizing/minimizing of applications they must do; who sits close together; arrangement of work stations; how convenient, clear, accessible are wall displays; is it difficult for individuals to hear each other over ambient noise; etc]
- Instances where people coordinate on tasks or overall process, or instances of a problem with the process and coordination (misdirects, someone left out, etc.)
  - any indications that process improves as team learns?
- Instances of “extra” work someone does for team members (e.g. converting kilometers to miles) to make things go smoothly (often without being asked)
- Humor, kidding around (possible sign of comfort and trust or lack of it)
- Yelling, grimacing, swearing, or other indications of confusion, stress
- Who people go to when confused, unclear about procedure, unclear where to get information
- Comments related to trust, relying on others, responsibility, credibility, confidence, or justifying their actions or decisions
- Discussions about coordination, goals, or priorities (“you do this”, “you should not do that”, “we need to do this before that”)
- Team expressions used repeatedly, and what is being conveyed by that expression
- Team norms or rituals (“say roger so I know you heard me”)
- Conflicts or confusion between multiple information sources or systems
- Discussions or search for metadata (accuracy, latency, trustworthiness, etc.)
- Indications they trust/don’t trust a tool or source (any indications why)
- How do they resolve conflicting information?
What to look for?

(Observation, continued)

- Instances of inappropriate information sharing
  - someone clearly needed it but didn’t get it (why)
  - someone was misdirected or overloaded by it (went to wrong system or person)
  - wrong information sent
- Instances where someone determines who should (or should not) get piece of information (rationale?)
- Manually intensive, repetitive, or awkward tasks
- Workarounds (systems don’t provide something needed)
- “Cognitive aids” (different from workarounds), such as charts, diagrams people post/create ad hoc to help them make sense of things (how are they used? what need do they meet?)
- How do people figure out where to focus their attention?
  - is it clear to them when new info they need to look at arrives?
  - is it clear to them what’s important and what is not or can wait?
- Conflicts between human entry and machine-to-machine, or ways in which new technology alters the human process?
- Impromptu switching of medium or directions to use other medium (“call me”, “I’m coming over”, “get me so-and-so”), and indications why (due to technical problems? deemed more appropriate mode for a particular goal?)
- Instances where people cue, alert one another (such as to key chat developments). Modality used?
- Instances where identity (name, rank, position, service) is in question
What to look for?

(Observation, concluded)

- Instances when one directs another to appropriate source, person (how prevalent?)
- Disagreements or efforts to convince another (approach? result?)
- How do team members adapt when IT fails?
- How do team members respond to something unexpected, non-routine?
  - what was the cue in their environment
- Instances where procedures change due to environmental factor
  - issue (time pressure, difficult aspect of scenario, boundary condition, etc.)
  - what changes: do they skip steps, use different means of communication, etc.
- Look for work pace (is everyone frantic? bored?)
- Any evidence of bottlenecks (is just one person frantic?)
What to look for?

3. Interviews

- What are the “basics” of your job/role?
  - What are the primary tasks you perform?
  - What are the most difficult/important aspects of your job?
  - How would you teach or mentor a novice to do their job?
  - How do you know when they learned to do their job – both instructional and unspecified criteria for competent success?
  - What kind of mental images or analogies help understand the job
- What is your role/part of the system? How do you see your job fitting into the system?
- Who do you get information from?
  - Are they located near you or in different locations?
  - How do you communicate with these people? How often?
- What tools do you use primarily?
- Do you usually get enough, not enough, or too much information? Examples?
- Can you recall instances where information was distributed inappropriately (to wrong person or system)? Result?
- What do you do when you get conflicting information?
- What tools do you trust or doubt, and why?
- What kinds of info do you trust or doubt, and why?
- Was your training, and the training of team members, sufficient? Appropriate?
What to look for?

(Interviews, continued)

- Any workarounds used?
- Any charts, diagrams you’re aware of people posting/creating ad hoc to help them make sense of things (different from workarounds)
  - what gap does this fill?
- Please describe a difficult situation in which you had to make a decision, but there wasn’t much time to make it.
  - what difficulties did you have to overcome, what would have helped?
- Are there cases where you don’t know where to get needed information?
  - who do people go to when confused, unclear about procedure, unclear where to get information?
  - how common is this?
- How do team members adapt and collaborate when IT fails them?
- What are the boundary conditions – when do procedures change or NOT work?
  - what are situations that trigger changes? (time pressure, scenario elements)
  - do people skip steps, use different means of communication?
  - how common are these procedural changes?
Ongoing Experiment: TST Team Decisions
n=3 (Leader/ISR Analyst, Sensors, Weapons)

Digitally recorded audio of team discussion

Digitally recorded video of team discussion

Synchronized Data Streams

Shared Whiteboard

TST tool actions

Whiteboard actions
Some Human-Centric Measures

- Number of people required for key tasks
- Time to perform key activities end-to-end
- Percent of time spent in collaboration and decision-making
- Percent of time spent on errors
- Time to acquire necessary information
- Number of operator workarounds needed
- Number of requests for information or clarification
- Perceived ease of use of tools
- Percent of identified threats prosecuted
- Percent of non-threat targets falsely prosecuted
- Ratio of successes to failures
- Frequency of help use
- Reported satisfaction with situational awareness
- Number of times operator is disrupted from a work task
- Number of times operators express frustration or satisfaction or confusion