Assessing Human-Autonomy Teams: How to Verify?

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BACKGROUND

• Unmanned platforms
  • These platforms will feature reduced crew-system ratios and will be controlled through a mix of manual teleoperation and autonomy.

• Integrating humans and autonomous systems into teams is complex
  – Humans and machines think, decide, and act differently
  – Machines operate at dramatically different time scales than humans
  – Humans and machines have different capabilities to adapt to mission demands

• Assessing human-autonomy teams is challenging.
  – Current methods focus on scripted evaluation scenarios that are expensive and periodic.

• Need assessment methods that can accommodate these new team characteristics and dynamics
  – Heterogeneous teams
  – Continuous assessment
  – Learning and adaptation
In response to the need for novel assessment methods, two software tools are being developed:

**Human-Autonomy Teaming Trust Toolkit (HAT³)**
- Goal: provide a multimodal approach to assess the dynamic nature of human-autonomy team trust in complex environments through real-time state estimation.

**Toolkit for Continuous Team Assessment (T-CAT)**
- Goal: provide a capability for collaborative, continuous team assessment via a software platform that enables re-streaming and analysis of human-autonomy teams in real/near-real time in order to improve team effectiveness.
HUMAN-AUTONOMY TEAMING TRUST TOOLKIT (HAT³)

Description: Modular software tool for continuous, unobtrusive, real-time, multimodal assessment of team trust and appropriate trust

Rationale: Existing trust measures rely solely on self-report which can be obtrusive and are unable to capture changes in trust and cohesion over time. A multimodal approach is needed to understand what impacts trust over time and identify when breakdowns occur so interventions for proper calibration can be implemented.

Features: 5 modules
• Subjective: self-report questionnaires
• Communication: communication flow, network analysis, linguistic analysis
• Physiological: heart rate, heart rate variability, pupillometry (in progress)
• Behavioral: eye-tracking, interface interactions (future)
• Affective: facial expression (future)

Targeted users: Researchers, analysts, vehicle commanders and commanding officers

Usage: Laboratory and Field
TRUST TOOLKIT - SUBJECTIVE MODULE

Description:
• 10 self-report measures of trust
  • Trait-based scales
    • Trust propensity
  • State-based scales
    • Interpersonal trust
    • Trust in autonomy
• 30 self-report measures related to trust
• Customizable

Historical view of one team member's scores over time. Colors indicate a continuous spectrum of subjective trust state which ranges from high (green ranges) to medium (yellow-orange ranges) to low (red ranges).
TRUST TOOLKIT – COMMUNICATION MODULE

Description:
• Three methods for visualizing and analyzing team communication that enable an understanding of team dynamics and trust
  • Real-time Event, Flow, and Coordination Tool (REFLECT)
    • Communication flow, rates
  • Network Analysis: in depth analysis of communication behaviors
    • Individual-level analysis
    • Team-level analysis
  • Bag of Words: linguistic analysis of communication content
    • Empath text analysis tool

NOTE: Data shown on next slides were collected from a vehicle crew of 7 members during a simulation experiment. Each crew station is labeled CS01 – CS07. Each crew member performed a specific role: Commander, Gunner, Driver.
TRUST TOOLKIT – COMMUNICATION MODULE

REFLECT: communication flow, rates

- Hover cursor over a crewstation to view percentage of time participant spent talking
- Line thickness indicates quantity of communication on the command network for crewstations 1 through 7 during a given timeframe
- Clicking on a crewstation allows user to view each participant’s time spent speaking on that network.
TRUST TOOLKIT – COMMUNICATION MODULE

Network Analysis: in depth analysis of communication behaviors

- **Individual-level measures**
  - Degree centrality
  - Betweenness centrality
  - Closeness centrality

- **Network-level measures**
  - Reciprocity
  - Clustering coefficient
  - Degree centralization
  - Betweenness centralization
  - Closeness centralization

- Left panel displays network statistics
- Adjustable sliding window to show how the network is changing over time (e.g., What did the network look like over the last 15 min? Over the last hour?).
- Attributes of individual nodes, such as size or color, can be modified in real time to reflect centrality scores. For example, nodes most important for routing information through the network could be enlarged relative to nodes with lower centrality scores.
TRUST TOOLKIT – COMMUNICATION MODULE

• Bag of Words: linguistic analysis of communication content
  • Uses *Empath* text analysis tool ([https://github.com/Ejhfast/empath-client](https://github.com/Ejhfast/empath-client))

• Evaluates number or words that fit different categories (positive or negative sentiment, perception cognition, past tense) as potential indicators of trust.
TRUST TOOLKIT PATH FORWARD

• Additional modules will be added:
  • **Physiological** – heart rate, heart rate variability (in-progress)
  • **Behavioral** – eye-tracking, interface interactions (future)
  • **Affective** – facial expression (future)

• Incorporate Human-Autonomy Team Cohesion scale

<table>
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<th>Item Scale</th>
<th>High Cohesion Scenario (p)</th>
<th>Low Cohesion Scenario (p)</th>
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• Expand capability beyond trust and cohesion to include system performance (autonomy) and other types of human performance measures and latent states of interest (e.g., situation awareness, workload, dynamic resource allocation, stress etc.)

• Developers working on scripts for ingesting additional data formats
TOOLKIT FOR CONTINUOUS ASSESSMENT OF TEAMS (T-CAT)

**Description:** Toolkit that consists of mission re-streaming and visualization software that enables the user to view mission data and metrics in real-time and view and manipulate data and metrics post hoc. The Toolkit is an integral part to the After-Action Review (AAR) to increase the Soldiers understanding of the human-autonomy teaming dynamic.

**Rationale:** Current methods used for assessing human-autonomy teams focus on simple use-case interactions in highly structured environments. T-CAT will enable continuous assessment of Soldier crews, autonomy, and their interactions in realistic, unscripted, and dynamic scenarios.

**Features:**
- Near-real time & post hoc data processing, synchronization, visualization, and analysis
- Near-real time & post hoc data annotation which enables users to log events as they occur to preserve critical data
- Embedded algorithms and predictive models estimate team’s overall effectiveness

**Targeted users:** Scientists, Engineers, SMEs, and Study Participants

**Usage:** Laboratory and Field
T-CAT ARCHITECTURE

Team Behavior

Human-Sensed Data

Autonomy-Sensed Data

Opportunistic Data Collection

T-CAT

Mission Visualization

Intermediate Analysis

Measures of Effectiveness

Performance Assessment

Outcome Prediction

Measures of Effectiveness

Opportunistic Data Collection

Human-Sensed Data

Autonomy-Sensed Data

Team Behavior
T-CAT INTERFACE
PAYOFF AND PATH FORWARD

HAT$^3$ and T-CAT assessment tools provide a capability for continuous assessment of the complex interactions that occur within human-autonomy teams in the NGCV context.

- Enables users to identify opportunities for training, adaptation, or trust interventions and ultimately improve human-autonomy team effectiveness.

**Final Capabilities:**

1. **Team performance management system that tracks and adapts team performance to maintain, intervene, and change behavior.**
2. **Assessment toolkit that enables S&T, Acquisitions, and T&E communities to characterize Soldier-Autonomy teams.**
OUR RESEARCH TEAM

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DCS Corp

Georgia Tech
School of Psychology
College of Sciences

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References:


THANK YOU.