Learning from Sensor-Based Analytics for First Responder Training

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Concurrent Presentation Session
LEARNING ANALYTICS FROM DIVERSE DATA

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Learning from Sensor-based Analytics for First Responder Training

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This material is based upon work supported in part by the National Science Foundation under Grant No. DRL-1637263, and IIS-1657379
Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation

Additional Support from the Center for Innovative Technology (CIT), the State of Virginia and the Department of Homeland Security Science & Technology Directorate
Engineering Digitally-Mediated Team Learning

Toward a Cyber-Physical System for First Responder Training

- Goal: learn from and shape individual and team behaviors/decisions, reduce cognitive bias, improve performance
- Can visualization of behavioral analytics improve within and cross-team learning in simulation debrief?
- How do we promote learning by first responders, inform and change team-based behavior in repeated, live simulation exercises?
- Can digitally-mediated teams self-monitor, adjust behavior and improve performance?
Design for Complex Sociotechnical Systems

- Operational
  - Physical setting of use
- Behavioral
  - Human activity
  - States of being
- Ecological
  - Networks of relationships
- Sociocultural
  - Shared ways of interpreting the world

Analyze distributed work & learning ecosystems
Digitally Mediated Team-based Learning – MTS System

• Multiteam Systems – Learning and Performance Across System

Team Stakeholders:
- Citizens on scene
- 911 Dispatcher
- EOC
- Fire & Rescue
- EMS

Team Stakeholders:
- EMS

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- ED/Trauma

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Multiteam System (MTS) Definition

“Two or more teams that interface directly and interdependently... While pursuing different proximal goals, [teams] share at least one common distal goal.” (Mathieu, Marks, & Zaccaro, 2001, p. 290)
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Toward these Methods and Objectives

- **Measurement** of dynamic coordination and learning of emergency response component teams and MTSs

- **Utilization** of new forms of data collection designed to uncover the nature of within-team and between-team behaviors
  - E.g., unobtrusive sensors, digital video and audio

- **Integration** of multiple streams of digital data in live simulation, dynamic contexts in real-time

- **Objective is to improve overall MTS coordination, learning & performance**
UX Design Prototype & Research Cycles

- Engineering wearable devices for learning
  - Bluetooth Proximity Beacons/
  - Location-based Sensing
- Tracing user activity and experience with connected devices
  - Determine activity trace
  - Based on real world activity and theoretical framework
Scene – Within Team Coordination

Figure 2. Officer and Firefighter/Paramedic addressing live simulated patient with observer.
Within Team Coordination

**Fig. 1** Proximity sensor data from officer and left bucket firefighter/paramedic with their proximity to fire engine over time during simulation.
Scene – Between Team Coordination and Patient Handoff in Field
Real-time team and individual activity tracing

Firefighter Suppression Team (blue) and Emergency Medical Services Team (red) proximity to EMS Medic (wearing listening device) visualized in near real-time on-scene.
In-the-Wild Design Research

- Active Threat (Shooter) Scenario
  - Map the team system/test IoT data collection, interrogate data for deeper analysis
Debriefing Session – Point of Learning
Engineering from First Responder Insights

Contextual Analysis - On-Site First Responder Interviews

- “Can we spatially see the configuration of personnel?”
- “Can we visualize tactics and how people are spread out?”
- “Are there clumps of officers congregating and not moving?”
- “First stop the killing, then stop the dying.”
- “How do we reduce time to treatment?”
- “Better facilitation of teamwork and systems.”
  - Positional timing
  - First on scene
  - How long to enter building
  - How is personnel spread out related to commands given
  - Etc.
Real-time Data Analysis of Team Behavior

• Location-based sensing – first responder in-building dynamic mapping

Courtesy of TRX Systems NEON Sensor Fusion and Dynamic Mapping for Location
Toward Integrated and Interoperable Data Streams

- Video, audio and radio communications capture, toward processing and analysis in near-real time

Courtesy of Mutualink Interoperability solution
Toward Data Stream Integration and Sensemaking

- Capture of location-based sensing, video/audio, radio communication
- Map the system initially to inform modeling/insights to inform event-based mining
- Temporally-based synchronization of data streams
- Modeling and visualization of first responder behavioral analytics for enhanced debrief
- Triangulation of data sources (e.g. human observer, sensor-based and video/audio data)
- Gathering insights that may provide impetus to move toward shared mental models to modify tactics?
- Inform labeling/event categorization – what can be machine-mined and what are human-in-the-loop processes?
- Upcoming design research iterative cycles
  - first responders reflect on their own (digitally-mediated) team behavior for enhanced learning, coordination and situation awareness – think aloud protocol
  - Examining individual and shared knowledge (e.g. mental models) as it develops through team interaction and reflection-on-action
  - provide input to help us optimally capture, label and integrate various streams of data to improve their learning, situational awareness and team coordination that matter to them?
Towards Interaction-based Team Cognition

• Human-Systems Integration
  • “...patterns of interactions among entities of a sociotechnical system are meaningful and can provide important indicators of a system state, such as change in state and the characteristics of that state (e.g. good performance, loss of situation awareness, poor coordination) (p.42).”

• Common-Operating Picture (COP)
  • “Coordinated perception occurs when team members interact in order to assess and build a coherent picture of the situation (p.40).”
    - Cooke & Gorman, 2009

• Interactive Team Cognition
  • “...team cognition is not a property of the individual, team members or the products produced by the team; team cognition is the interactions of the team members, and this assertion is counter to traditional approaches to studying team cognition (p.267).

  • “Thus, there is an overriding temporal component to team cognition because team interactions unfold over time. It follows from this premise that team cognition is inherently dynamic. Thus, computational and/or mathematical methods for describing dynamic processes provide the means for examining these principles of changing coordination....(p.268)”
    - Cooke, Gorman, Myers & Duran, 2013
Engineering System - Multimodal Stream Analytics

Multimodal Sources
- Social & Web Data Stream
- 911 Call Message Stream
- Resource Sensor Stream

Streaming Data Collector

Streaming Information & Behavior Mining

ICS model

Team Coordination
- What-Where-When Resource Analysis
- Enhanced Situation Awareness
- Experiential Learning
- Personnel & Performance Management Analysis

Visual Analytics along Operational Tasks

BACKGROUND KNOWLEDGE BASE
- Organizational Process Knowledge, Socio-Psychological Theories, Open Gov Data, Mobile-behavioral Analytics APIs, Learning and Performance of First Responders and Medical Teams in Live Simulations
CitizenHelper System: Extensible Stream Processing Architecture

- Supports in-memory and web service-driven multimodal data processing

Ingest a variety of streaming data sources

CitizenHelper Prototype: IoT Sensor Analytics

Behavioral Event Detection

[Image: CitizenHelper Prototype diagram showing data analysis and behavioral event detection]

[Purohit, Dubrow, & Bannan, HCII-2019]
Scene – Patient Handoffs
Figure 1. Healthcare MTS Example

Figure 2. Timeline: MTS Member Physical Contact with and Proximity to Simulated Patient.

PH = Pre-Hospital Team (Green). ED = Emergency Department Team (Blue). PH1 = Paramedic. PH2 = Firefighter. PH3 = Driver. ED1 = Respiratory. ED2 = Radiology. ED3 = Surgery Junior Resident. ED4 = Surgery Senior Resident. ED5 = ED Doc.
## Toward actionable Insights for First Responders

### Table 1.1 Transformation from tradition-based fire fighting to Smart Fire Fighting.

<table>
<thead>
<tr>
<th>Current State</th>
<th>Future State</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tradition-based tactics</td>
<td>Data-driven science-based tactics</td>
</tr>
<tr>
<td>Local information</td>
<td>Global information</td>
</tr>
<tr>
<td>Data-poor decision making</td>
<td>Information-rich decision making</td>
</tr>
<tr>
<td>Lack of awareness</td>
<td>Situational awareness</td>
</tr>
<tr>
<td>Untapped or unavailable data</td>
<td>Comprehensive data collection, analysis, and communication</td>
</tr>
<tr>
<td>Isolated equipment and building elements</td>
<td>Interconnected equipment and building monitoring, data, and control systems</td>
</tr>
<tr>
<td>Human operations</td>
<td>Human controlled, collaborative, and automated operations with inanimate objects (buildings, machines, etc.)</td>
</tr>
</tbody>
</table>
Toward Data-driven Science Insights

• Deeper dive into theoretical constructs informing data collection/analysis
  • Interactive team cognition/tactics
    ITC theory proposes that team cognition exists in the dynamic flow of team member interaction, and retrospective accounts
  • How to support reflection-on-action and transfer in a pro-active and offensive manner through live simulation training
  • To achieve the ultimate goal – improve performance to save lives
  • How teams work together as a system
  • Focus on explicitly revealing intrateam and interteam behavior
    • Toward shared mental models and improved coordination by the team
    • Learning as an MTS system – interdependent teams
    • Tacit knowledge and explicit knowledge – making the tacit explicit
    • Uncover patterns of behavior and communication
    • Analyze quality or totality of communication
    • Interaction among people, processes, components – in a socio-technical system
Selected References


• Purohit, H., Dubrow, S., & Bannan, B. (2019). Designing a multimodal analytics system to improve emergency service training. To be presented at the 5th annual HCI International Conference on Learning and Collaboration Technology.


Thank You!

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Fairfax County Fire & Rescue Department
Inova Fairfax Medical Center Advanced Surgical Technology Education Center (ASTEC)
Center for Innovative Technology (CIT)
Department of Homeland Security Science & Technology Directorate