Addressing the Research Practice Gap in Pre-Incident Planning through Simulation-Based Case Studies

Special thanks to collaborators Dr. Joseph Bonnell and Dr. Charles Jennings

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Speaker Bio

Current: Contract Instructor for the National Fire Academy, EFO Program

Postdoctoral Research Associate, supporting NIST PSCR through Brown University School of Engineering

Research Statistician Orange County Fire Rescue Department

Former Research Psychologist for DoD/US Navy (F-18 pilots, JTACs, and undersea)

Intern with East Central Florida Regional Planning Council, developed CAMEO files and modeled chemical plumes for HazMat response in four large Central Florida counties

Ph.D. in Modeling and Simulation from the University of Central Florida
Overview

• Introduction and Background
• Overall Research Program/Methods
• Relevant Results
• Future Work
Introduction and Background
Pre-Incident Plans

Pre-incident planning developed from a need for firefighters and first responders to understand the critical elements of a structure and to develop tactical decisions based upon anticipated conditions.
Introduction

Because no current standard exists for presenting and displaying pre-incident planning information electronically, this work provides baseline measures for capturing performance related to pre-incident planning tasks.

Additionally, this work informs how future systems should highlight critical cues on the fireground to better support fireground incident commanders operating in high stakes environments.
What is the research problem?

Due to rapid advances in technology, first responders will eventually have access to building information, sensor data, and fire protection system data in real time.

The presentation and display of this information *has not been fully evaluated from the human performance perspective*.

The goal of this work is to investigate how to design simulations that can better support incident command decisions making and improve the ability for incident commanders to *anticipate changing conditions*. 
### Research Program to Date

<table>
<thead>
<tr>
<th>Study 1: Work Domain Analysis</th>
<th>Study 2: Model for Incident Assessment</th>
<th>Study 3: Online Survey Pre-Incident Planning Practices</th>
<th>Study 4: Online Study of User Interface Prototypes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field Studies</td>
<td>Dataset from Study 1</td>
<td>Online Survey</td>
<td>Online User Study</td>
</tr>
<tr>
<td>Focus Groups</td>
<td>Theoretical Model</td>
<td>33 Questions</td>
<td>Plan Type (2D/3D), Visualization (Symbols, See-Through, Control)</td>
</tr>
<tr>
<td></td>
<td>$n = 35$</td>
<td>$n = 50$</td>
<td>$n = 64$</td>
</tr>
<tr>
<td></td>
<td>(from previous field study/focus groups)</td>
<td></td>
<td>$n = 54$</td>
</tr>
</tbody>
</table>
What is a “Size-Up”? 

• An appraisal of the magnitude or dimension of an incident
  – Involves understanding building construction and critical “cues and clues” in the environment

• Size up information can typically be gathered 3 ways:
  – Visual (line of sight, or what you can see)
  – Reconnaissance (information you get from additional resources)
  – Preplanning and familiarity (previous experience or exposure)
Methods
User Study Design

2 Part User Study

Independent Variables

• Part A: 2D to 3D Comparison
• Part B: Visualization Comparisons

Dependent Variables

• Efficiency
• Effectiveness
• Satisfaction
• Open-Ended Questions (Content Analysis, open-coding methodology)
User Study Design

The following narrative represents the on-scene report you provided via radio:

E-1 to alarm....E-1 is on scene of a large commercial retail store with dark, pressurized smoke showing from the rear of the structure. E-1 will be laying a supply line from northeast and pulling a horizontal standpipe to the interior of the structure for fire attack. This is a working fire. We are in the offensive strategy. E-1 is assuming Main St. Command. Further report to follow.

Scenario details:

This is a very large commercial structure. The building was constructed in 2010, using tilt-slab walls and a lightweight metal paneled roof. The occupancy is approximately 160,000 sq ft. The building is equipped with a sprinkler system, but lacks a pumping station. The city supplies the water. The incident occurs mid-afternoon on a weekday, so we assume that occupants are able to escape and that the store is not at maximum capacity (parking lot is accessible).
User Study Design

- Unity 3D
- Qualtrics
- Client-Side Scripting
Big Box Store: 2D to 3D Comparison (Part A)

Part A \( n = 64 \)
Part B \( n = 54 \) (1 female)
Warehouse Prototype (Part B)

Part A  \( n = 64 \)
Part B  \( n = 54 \) (1 female)
Dependent Measures**
Due to the scope and purpose of this presentation, we will not cover all of these

**Effectiveness**
Correct Multiple-Choice Answers
Well-Formed Incident Action Plan (IAP)

**Efficiency**
Time
Workload (NASA-TLX)
Situation Awareness (SART)

**Satisfaction**
Qualitative Feedback
System Usability Scale (SUS)
Technology Acceptance Model (TAM)
Results
## Demographics

<table>
<thead>
<tr>
<th>Rank</th>
<th>Participant Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assistant Chief</td>
<td>10</td>
</tr>
<tr>
<td>Battalion Chief</td>
<td>11</td>
</tr>
<tr>
<td>Captain</td>
<td>5</td>
</tr>
<tr>
<td>Deputy Chief</td>
<td>8</td>
</tr>
<tr>
<td>District Chief</td>
<td>1</td>
</tr>
<tr>
<td>Driver/Operator/Engineer</td>
<td>1</td>
</tr>
<tr>
<td>Fire Chief</td>
<td>14</td>
</tr>
<tr>
<td>Firefighter</td>
<td>5</td>
</tr>
<tr>
<td>Lieutenant</td>
<td>8</td>
</tr>
<tr>
<td>Senior Firefighter</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>64</td>
</tr>
</tbody>
</table>

- **Part A** \( n = 64 \)
- **Part B** \( n = 54 \) (1 female)

### Age

- \( M = 50 \)
- \( SD = 10.26 \)
- \( Md = 49 \)
### Time on Task (measured in seconds)

**Part A**  \( n = 64 \\
**Part B**  \( n = 54 \) (1 female)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Count</th>
<th>Mean</th>
<th>Std Dev</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2D</strong></td>
<td>30</td>
<td>283.07</td>
<td>89.84</td>
<td>244.52</td>
</tr>
<tr>
<td><strong>3D</strong></td>
<td>34</td>
<td>225.68</td>
<td>172.28</td>
<td>207.14</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Condition</th>
<th>Count</th>
<th>Mean</th>
<th>Std Dev</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Symbols</strong></td>
<td>20</td>
<td>412.59</td>
<td>244.88</td>
<td>364.56</td>
</tr>
<tr>
<td><strong>Shaders</strong></td>
<td>19</td>
<td>464.56</td>
<td>272.46</td>
<td>364.76</td>
</tr>
<tr>
<td><strong>Control</strong></td>
<td>15</td>
<td>465.95</td>
<td>278.29</td>
<td>443.88</td>
</tr>
</tbody>
</table>
### SUS Results

**Part A**  \( n = 64 \)
**Part B**  \( n = 54 \) (1 female)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Count</th>
<th>Mean</th>
<th>Std Dev</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>2D</td>
<td>30</td>
<td>72.82</td>
<td>19.28</td>
<td>75.00</td>
</tr>
<tr>
<td>3D</td>
<td>34</td>
<td>75.35</td>
<td>15.51</td>
<td>75.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Condition</th>
<th>Count</th>
<th>Mean</th>
<th>Std Dev</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symbols</td>
<td>20</td>
<td>78.00</td>
<td>21.82</td>
<td>86.25</td>
</tr>
<tr>
<td>Shaders</td>
<td>19</td>
<td>78.83</td>
<td>16.95</td>
<td><strong>87.50</strong></td>
</tr>
<tr>
<td>Control</td>
<td>15</td>
<td>70.62</td>
<td>20.98</td>
<td>71.25</td>
</tr>
</tbody>
</table>
## Qualitative Codebook (Concept Analysis)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Big Box Store Plan Type (2D/3D)</td>
<td>Usability&lt;br&gt;Visual Assessment &amp; SA&lt;br&gt;Resource allocation&lt;br&gt;Additional Features</td>
</tr>
<tr>
<td>Warehouse Visualization Type (Symbols, Shaders, Control)</td>
<td>Location&lt;br&gt;Scale&lt;br&gt;Responsibilities</td>
</tr>
<tr>
<td>Open-Ended Questions (All)</td>
<td>Fidelity&lt;br&gt;Colors&lt;br&gt;Implementation&lt;br&gt;Input Methods&lt;br&gt;Efficiency/Time</td>
</tr>
</tbody>
</table>
Example of Qualitative Data

Ex. Exploit the details from this quote:

The underlying data for this system has to be collected so that it can be used in realistic scenarios. One cannot have every structure or facility in the database without becoming too unwieldy and difficult to maintain.

However, it would be better to use real-life examples so that the crews can orient to the hazards that actually exist in their service areas. The tool will only be as good as the persons operating it.

To pick one example, how many training personnel would develop a scenario using this tool for a mixed-use gas station and souvenir shop, and would then incorporate the hazard (heavy flammable attic storage) that killed two of their fellow firefighters 25 years ago? The uses for this system are almost limitless, even including using drone aerial photography in the training and also when the fire occurs, but the learning curve is fairly steep and the training demanding. –Chief, Retired
To Recap

• Provide both objective and subjective evaluations to better understand firefighters’ perceptions of an interface designed to assist in conveying pre-incident planning data in the context of two simulated commercial structure fire scenarios
Limitations of the Research

COVID-19 Constraints

Ecological validity of baseline measurements
Subjective measures ("the best we have")
NASA-TLX and SA are correlated
SART demonstrates a relationship with experience (previous lit in aviation)

Generalizability
Small subset of problems (e.g., stabilizing water supply can be less difficult than a HazMat scenario, more complex commercial fire, mass casualty incident, etc.)
Discussion & Practical Implications
What does this mean for the fire service and fire engineering communities?

Focus on all stakeholders involved across the pre-planning process. This topic has relevance because the NFPA 1620 standard is slipping cycle and the entire standard will be rolled into a new standard, NFPA 1660.
NFPA 1620 to NFPA 1660

- Enhance communication and understanding amongst the engineering and tactical fire suppression stakeholders, emphasizing on the proactive aspects of pre-incident planning.

- “Whole Community Approach”
Practical Implications

- Accreditation
  - ISO
  - CPSE
- Training and Building Familiarization
- Multi-agency response
Practical Considerations

Theoretical Model that Illustrates the Importance of Situated Visualization for Size-Up

Subjective data collected on perceived utility of PIPs in United States

Methodological & Practical contributions: Best practices for working with firefighters on technical issues

We currently have no formal data on pre-incident planning effectiveness, other than accident investigation reports.

Outline of issues where problems with PIPs extend beyond usability, it's a sociotechnical problem, not a user experience problem
In a perfect world… (addressing limitations)

Methods: Increase sample size, larger budget, in-person user studies, study timelines

⚠️ Build in simulation to demonstrate changing fire conditions (ecological validity)

🛠 Tailor, refine, and iterate on rapid prototypes

💡 Run a series of studies and conduct larger-scale analyses
Areas for continued/future research

- Community Risk Reduction Efforts
- Social Vulnerability and Inclusion
- Privacy, transparency, and security of data (data sharing between agencies and the public)
Contact Information

• Thank you for your time and attention today.
• Happy to answer further questions or to send copies of published research
• Please email Dr. Kate Kapalo at drkapalo@gmail.com