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Human Limits to Cognitive Information Fusion in a Military Decision-Making Task

ARL

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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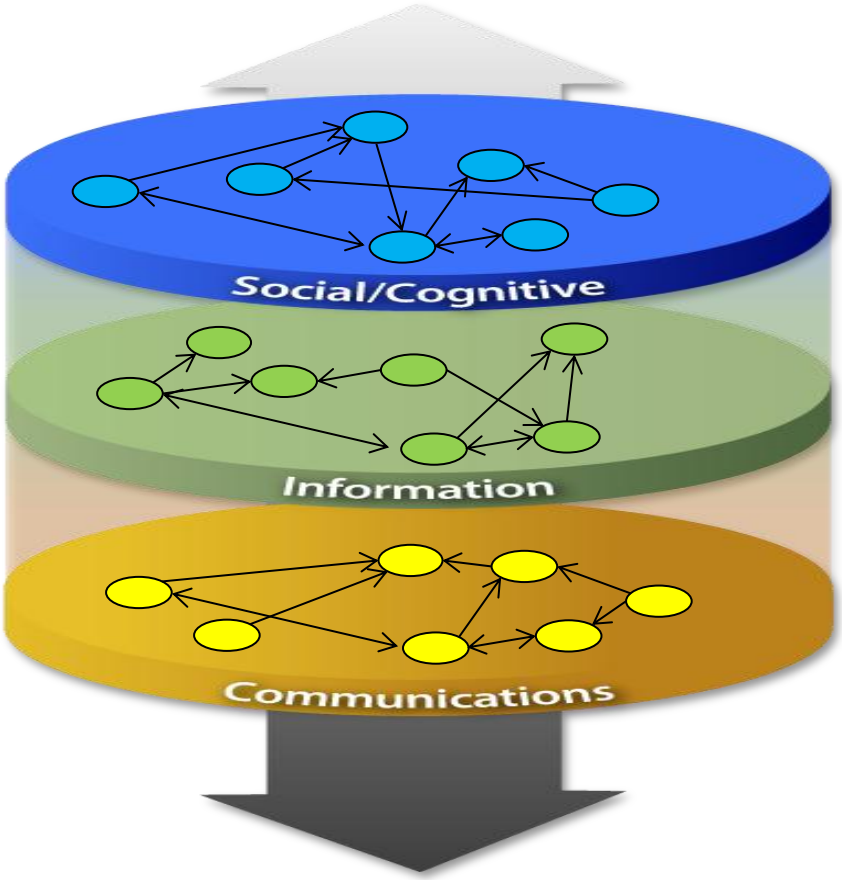
Motivation

- Transition to Network-Enabled Operations
- Vast number of potential collaborations
- Vast amount of available information
- How is human decision-making affected?



Motivation

- Tenets of Network Centric Warfare:
  - A robustly networked force improves information sharing
  - Information sharing enhances the quality of information and shared SA
  - Shared SA enables collaboration and self-synchronization and improves the sustainability and speed of command
  - These dramatically increase mission effectiveness

Alberts, D., & Garstka, J. (2004)

More Information → Improved Performance

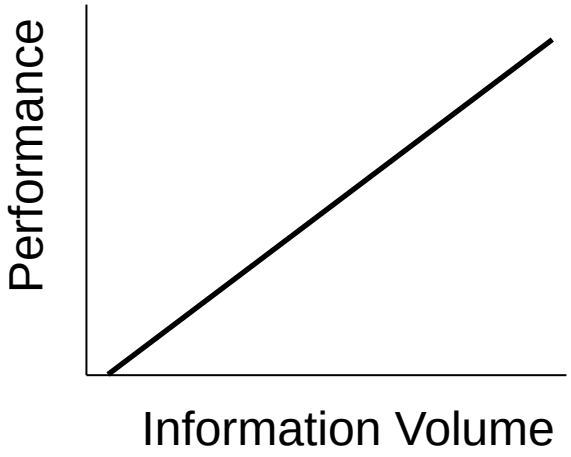
Motivation

- Information Overload
  - More information does not necessarily lead to better decision-making
  - Studies:
    - Worse performance with multiple types of available information (overnight temperature prediction task) Nadav-Greenberg & Joslyn (2009)
    - U-shaped relationship between information available and information used (prediction of firms' financial distress) Chewning & Harrell (1990)
    - No performance improvement with additional relevant information (city ranking task) Goldstein & Gigerenzer (2002)
    - Decreased accuracy with additional information (prediction of pro basketball game outcomes) Hall, Ariss, & Todorov (2007)

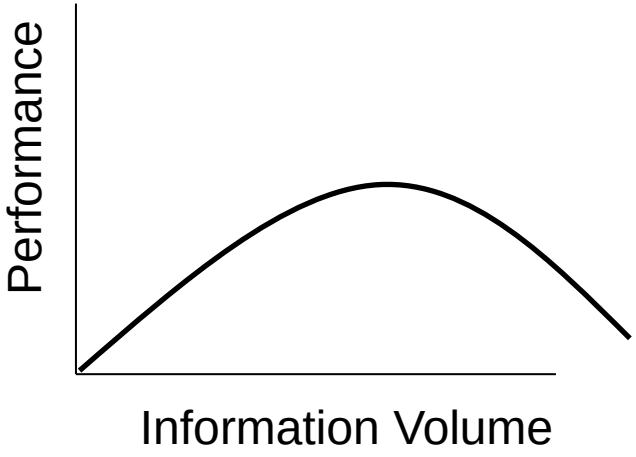
Too Much Information → Worse Performance

Hypotheses

- More is More



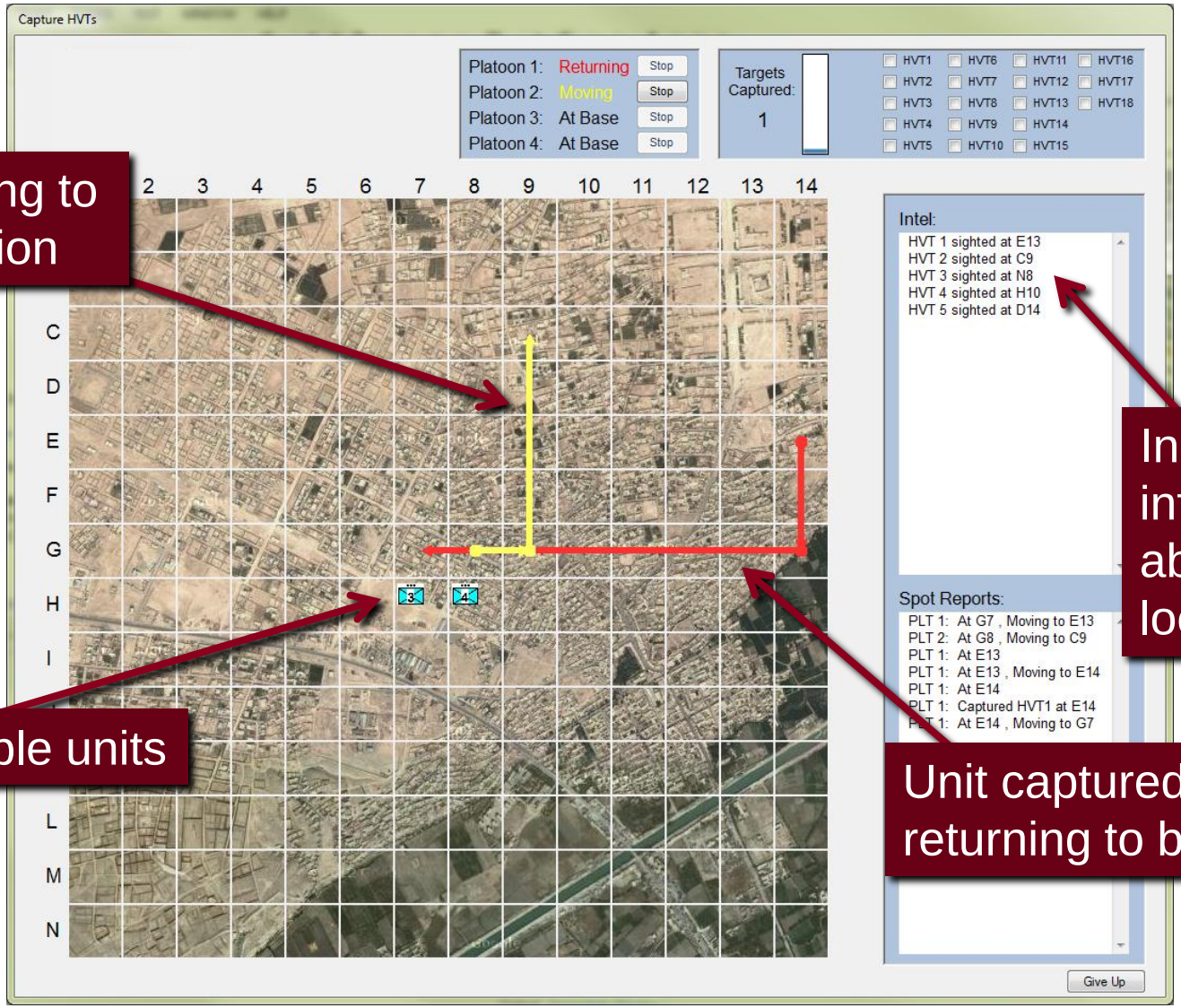
- More is Less



Task

- Simplified C2 mission
- Computerized task, grid-based map
- Primary Goal: Find and capture high value targets (HVTs)
- Text updates provide information about possible HVT locations

Task



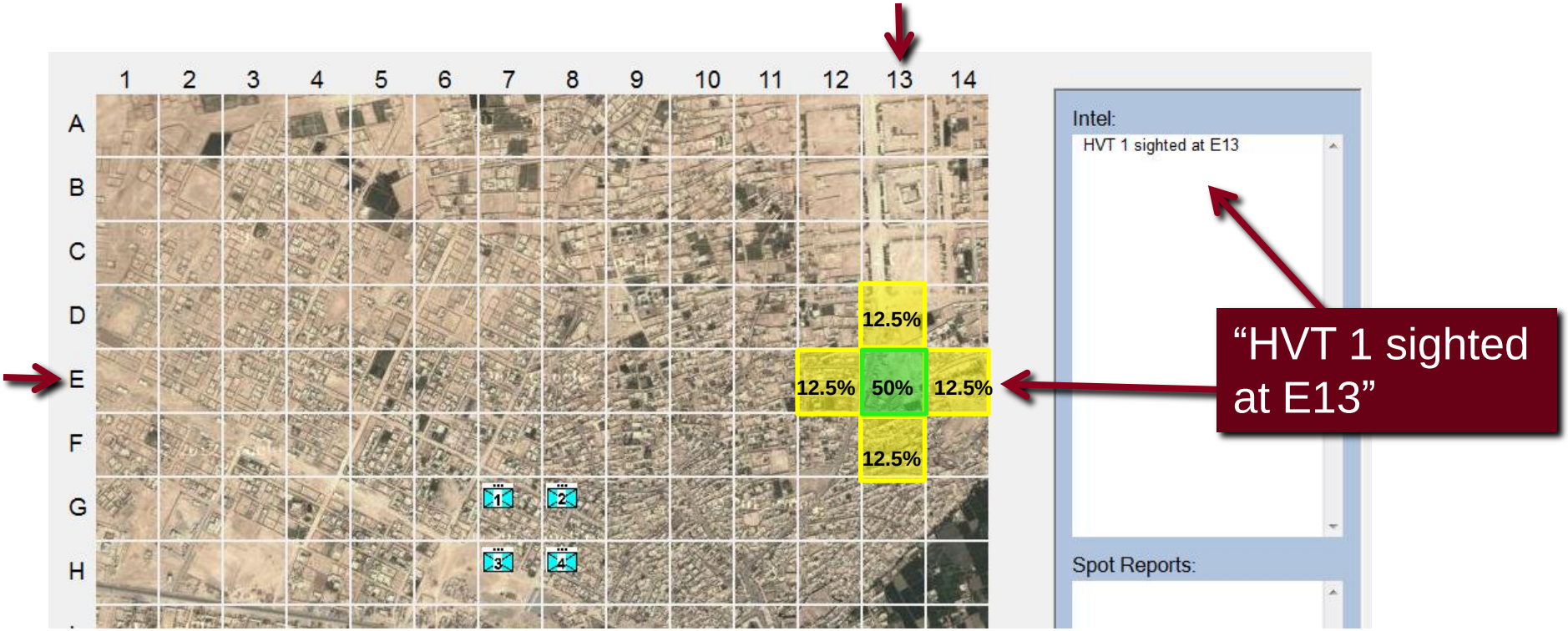
Unit moving to new location

Controllable units

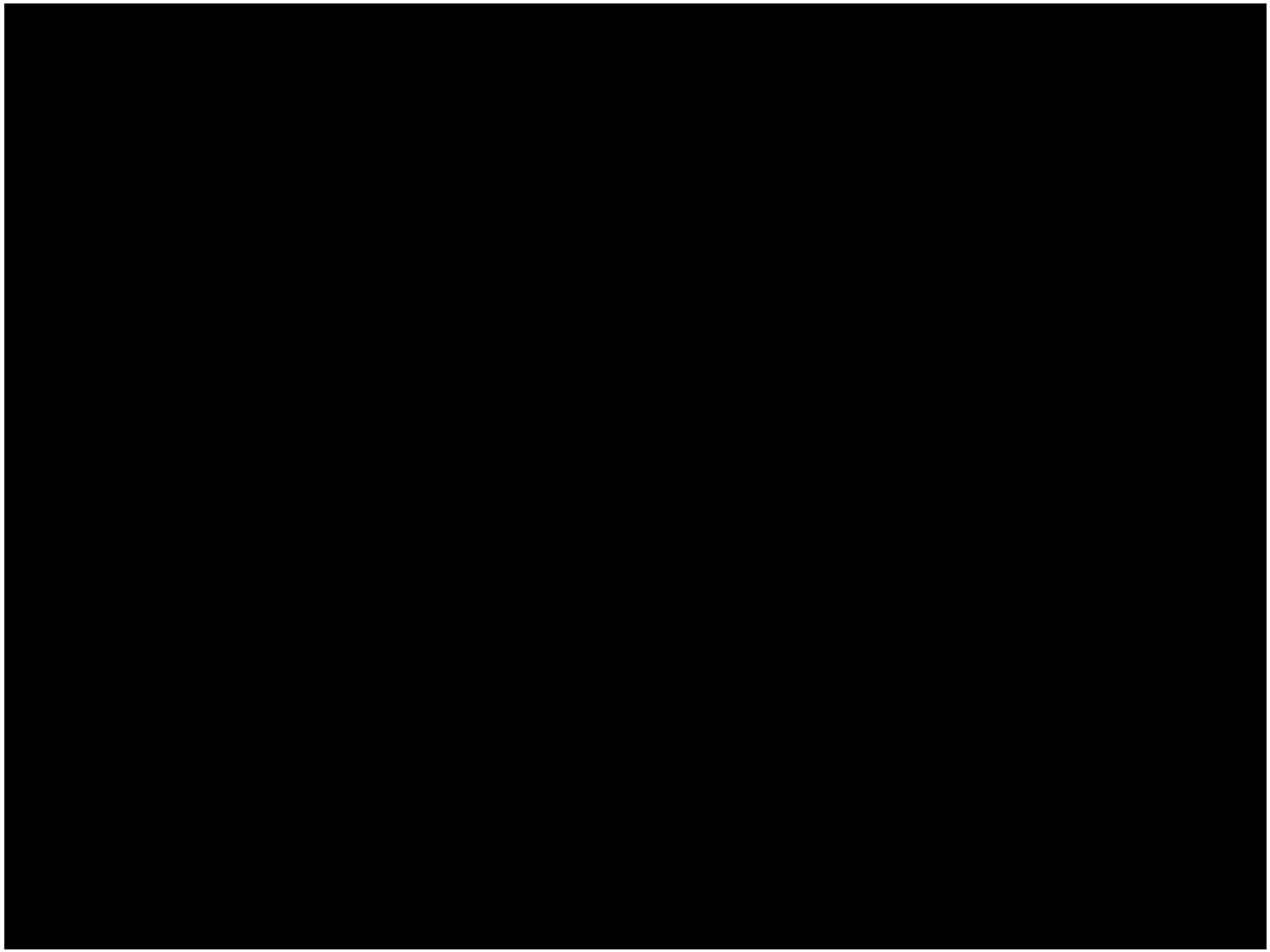
Incoming information about HVT locations

Unit captured HVT, returning to base

- Every update 50% likely to be correct
- If incorrect, off by one square (horizontally or vertically)



Task

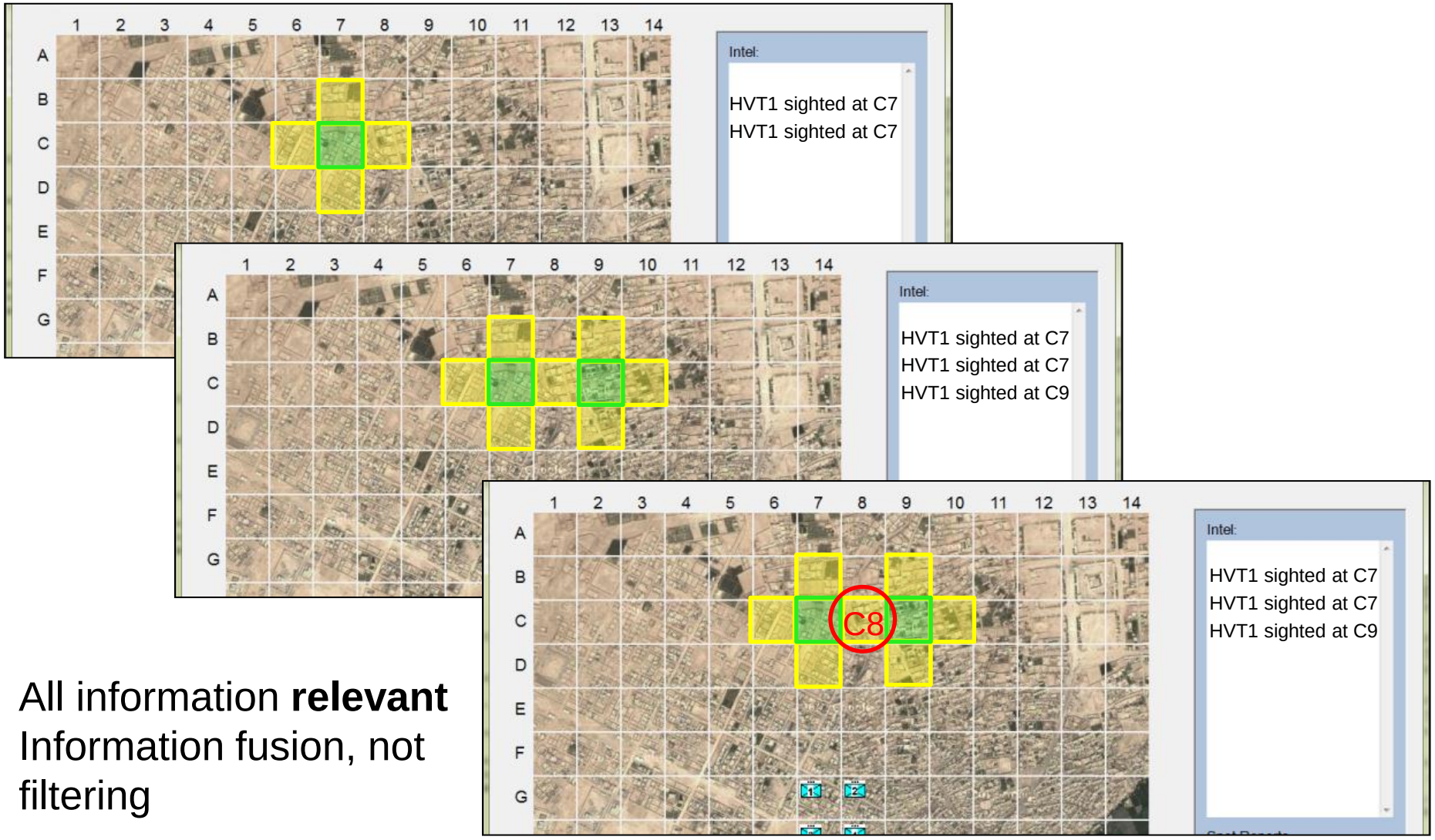


Design

- Independent Variable:
  - Information Volume
    - Within-subjects manipulation
    - Three conditions:
      - **Low** (1 location update for each HVT)
      - **Medium** (5 location updates for each HVT)
      - **High** (9 location updates for each HVT)

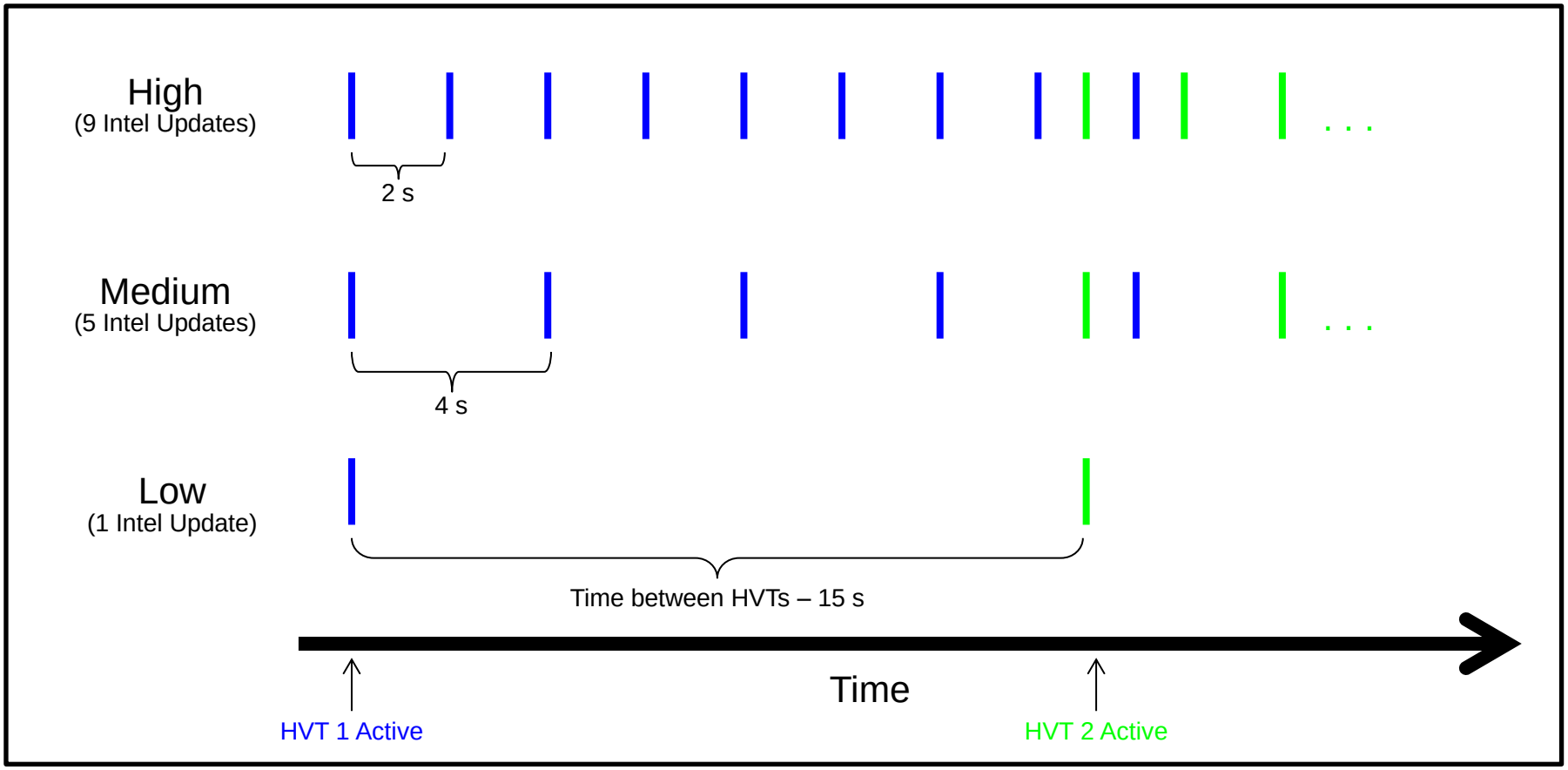
- Dependent Variable:
  - Time to capture targets

Location Information



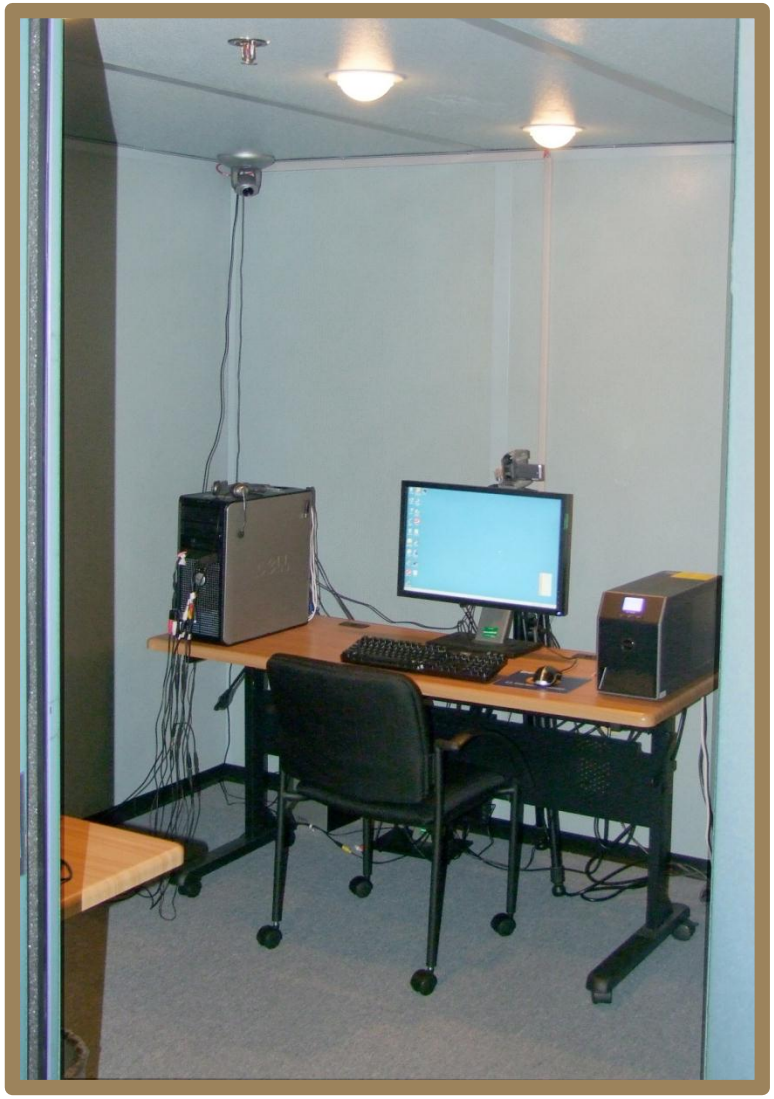
- All information **relevant**
- Information fusion, not filtering

Design



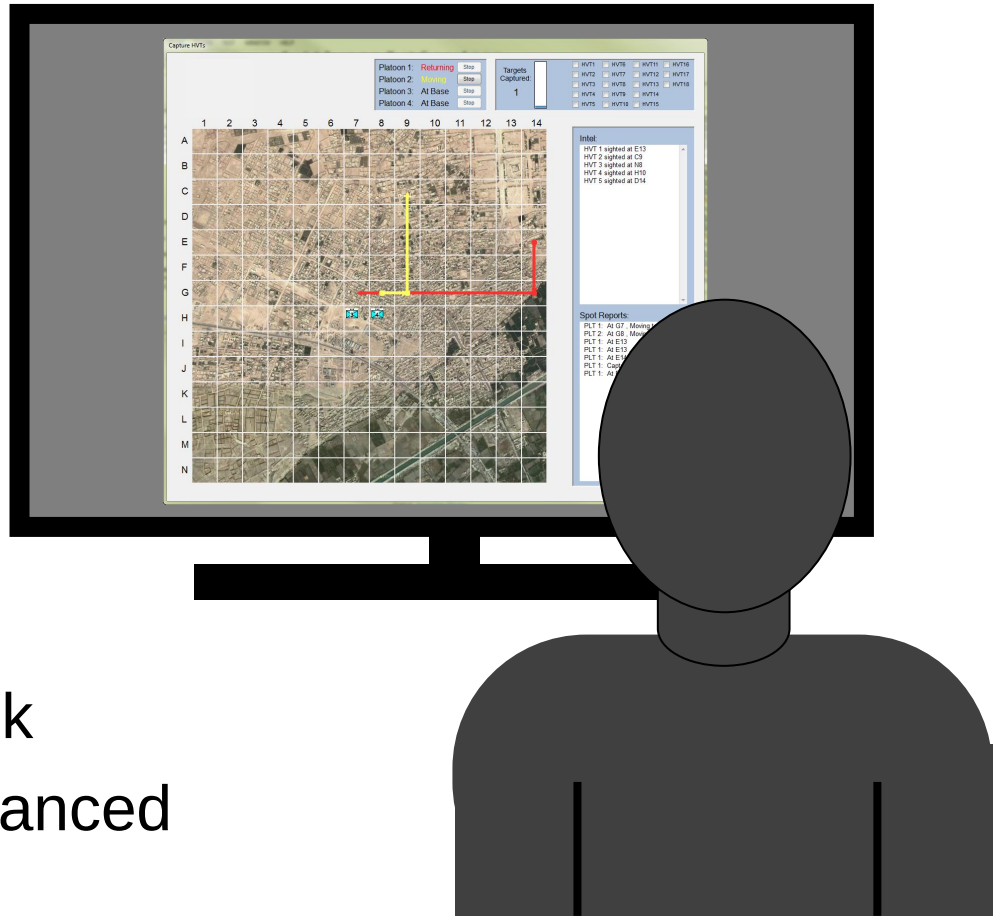
Participants

- 24 participants
  - 16 male
  - 8 female
- Age: 18 – 60 years
- Recruited from ARL workforce



Procedure

- Informed consent
- Self-paced tutorial
- Practice block
  - 6 targets
- 3 test blocks
  - One block for each information condition
  - 18 targets in each block
  - Block order counterbalanced across participants



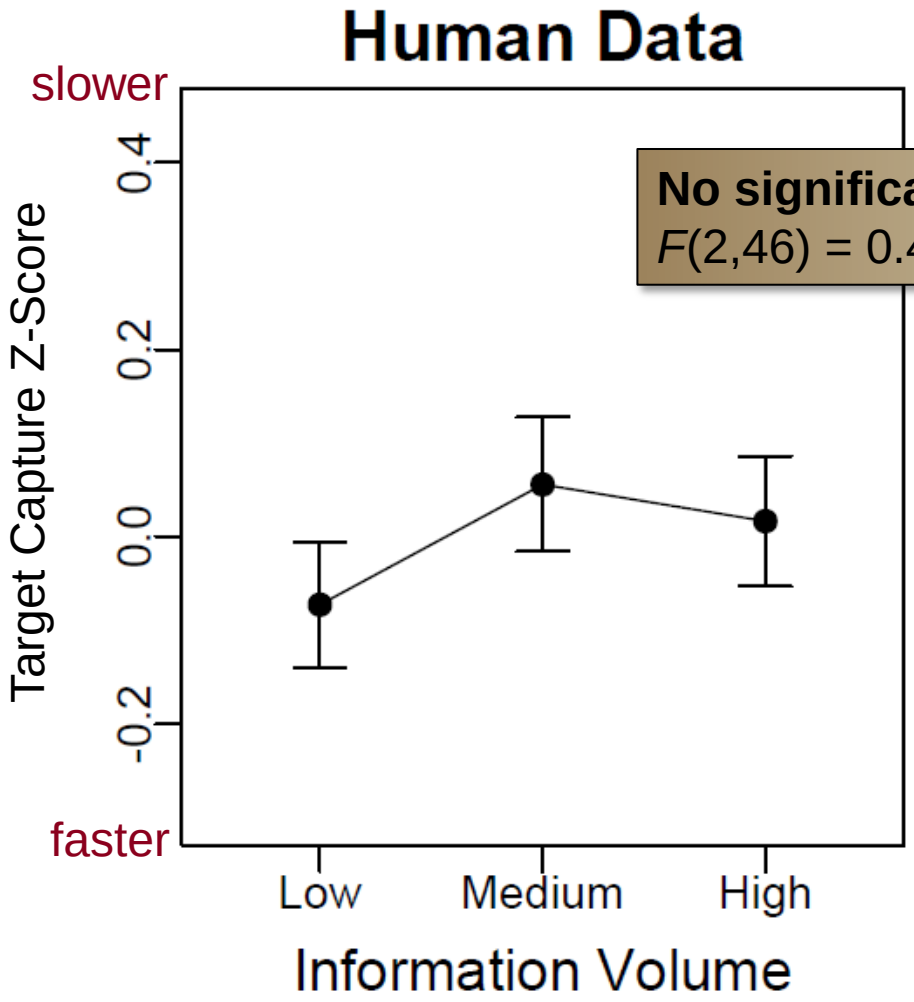
Analysis

- Target Capture Time =

  (Time of Capture) – (Time of 1st Location Update)

- Normalized by distance from base location to target location
- Standardized (converted to z-scores) for each participant
- Average z-scores calculated for each information volume condition

Results



No significant differences:
$F(2,46) = 0.49$, $p = 0.62$, $\eta^2 = 0.02$

Ideal Observer Model

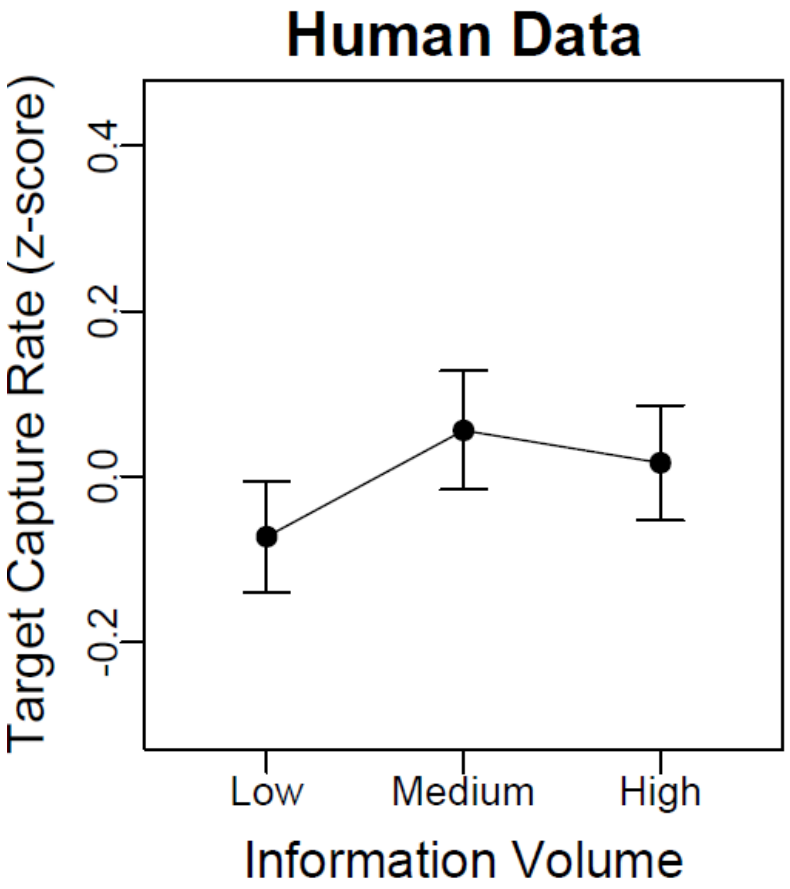
- Ideal Observer Models
  - Purpose: “to determine the optimal performance in a task, given the physical properties of the environment and stimuli” (Geisler, 2006, p. 825)
  - Useful comparison for actual human performance data

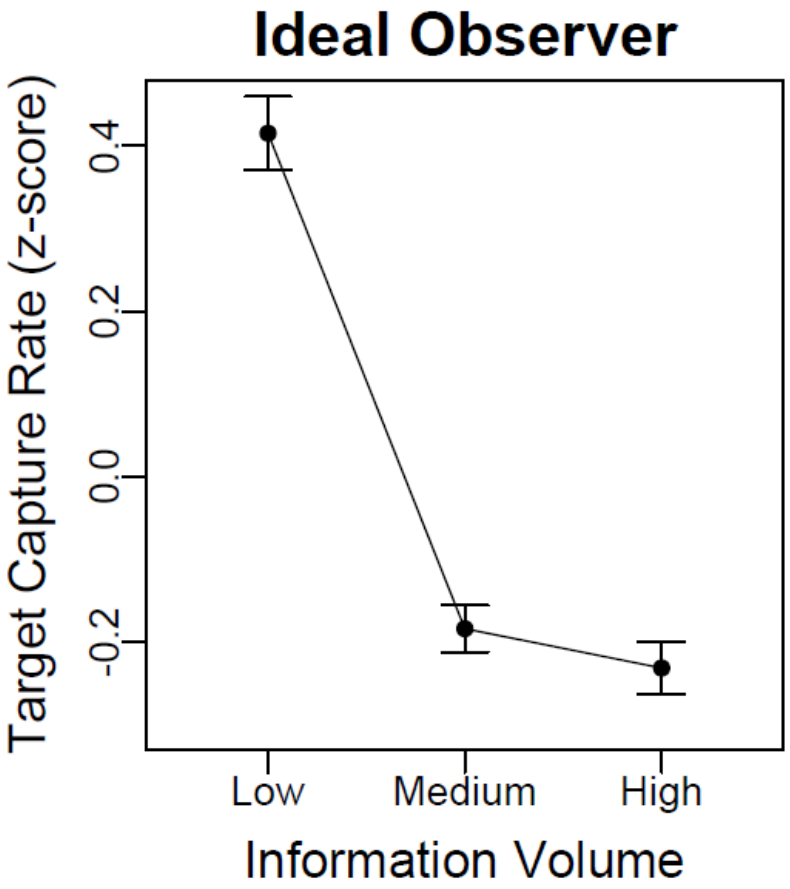
- Our IOM:
  - Demonstrates what perfect information fusion looks like for this task
  - Performs information fusion by integrating all of the information presented to the user
  - Receives same sequence of location updates as human participants
  - Algorithm

    1) Assigns closest unit to location specified in first location update

    2) After each new update, uses information provided in previous updates and task-specified location probabilities to predict a target’s most likely location.

Results





Significant differences between human data and Ideal Observer:
$F(2,90) = 19.44$, $p < 0.0001$, $\eta^2 = 0.30$

Results

- Human Data:
  - ~~More is More~~
  - ~~More is Less~~
  - More is the Same
- Ideal Observer
  - More is More

Conclusions

- IOM data:
  - Computational performance can be improved by integrating all available information
- Human data:
  - Neither improved nor degraded with increasing information volume
  - Not taking advantage of all available information
- Suggests human participants in this task were at their limits for fusing information

Limited Human Information Fusing Capability

Conclusions

- **Limited human information fusing capability**
  - Not a clear benefit to attempting to make all information available to all personnel in C2 environments
  - Strong case for continued development of effective decision-support tools that can assist in information synthesis and disambiguation
- **Future work**
  - Explore the optimum interaction between automated fusion algorithms and human cognitive fusion in similar simulated experimental C2 tasks
  - Increase task complexity:
    - Multiple interacting roles
    - Introduces team dynamics, communication, and trust
    - Richer data sets
    - Deeper investigation of human decision-making performance in networked operational environments