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Effects of Professional Visual Search Experience on Domain-General and Domain-Specific Visual Cognition

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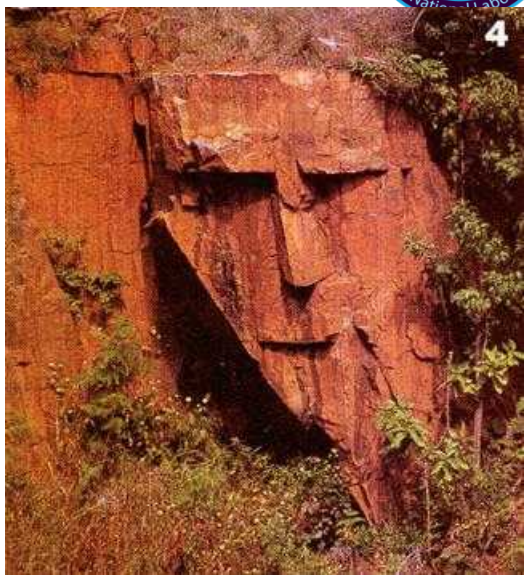
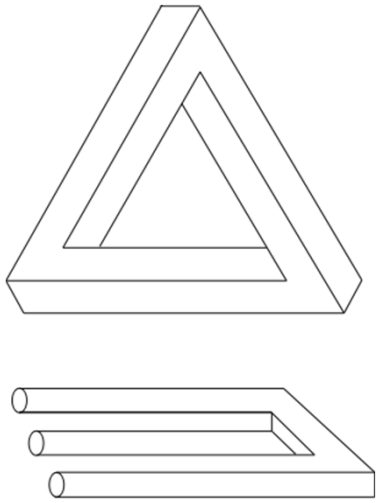
Visual Cognition Basics

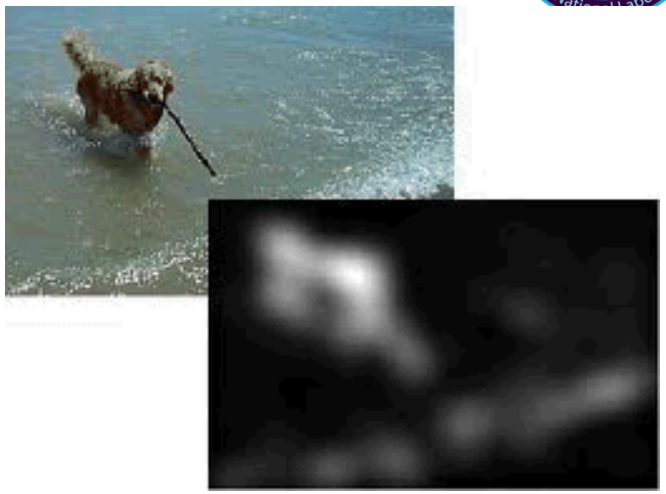


- The human visual system is VERY good at:
  - Finding patterns
  - Making inferences
- Perceptual systems are constantly receiving ambiguous information and trying to make sense of it
- Draws on both perceptual cues and conceptual knowledge (bottom-up and top-down processing)
  - Relatively little is understood about top-down processing

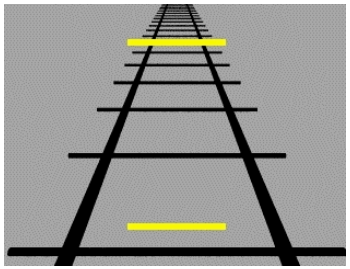


Visual Attention

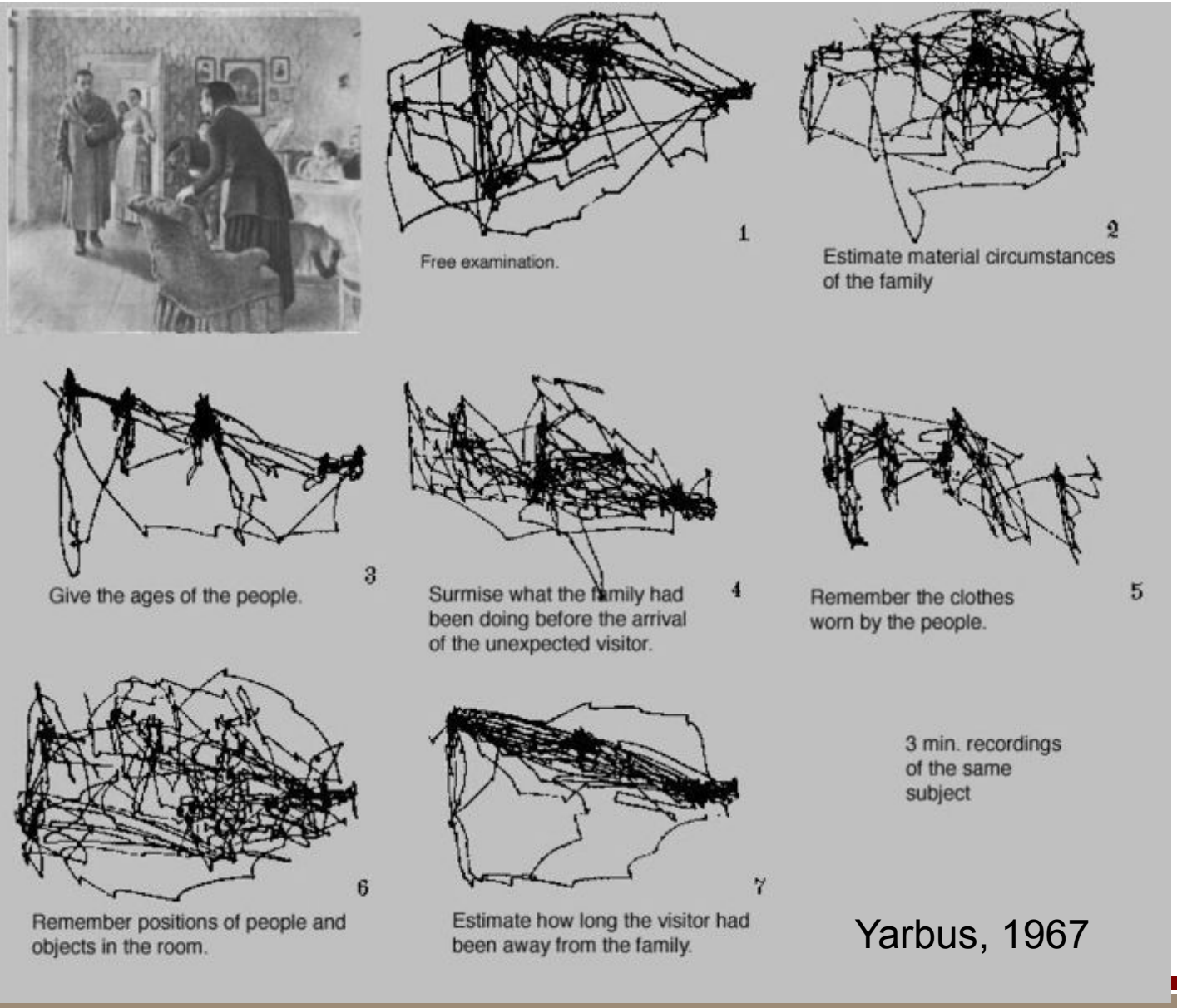
- Bottom-up
  - Driven by properties of stimulus
    - ***Visual salience*** (contrast between features of a stimulus and the features of its neighbors) captures attention
  - Parameters are well understood and can be modeled



- Top-down
  - Driven by viewer's goals
  - Affected by cognitive load, working memory, past knowledge and experience
  - Has a very powerful influence on bottom-up perception
  - Parameters are NOT well understood



Top-Down Control of Eye Movements



Yarbus, 1967

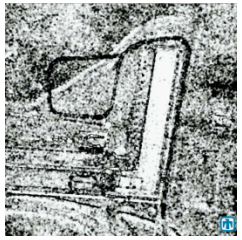
Illustrates top-down aspects of visual search:

- The person's task influences eye movements

Core Scientific Questions:

What features capture attention in different kinds of imagery?
How does domain experience influence visual search/inspection?
How can top-down visual attention be modeled?
Do people with expertise in one domain perform differently on domain-general tasks?

SAR
CCD Products

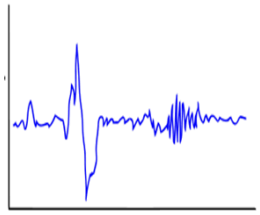


Intended to make important features more salient

TSA
False color X-rays

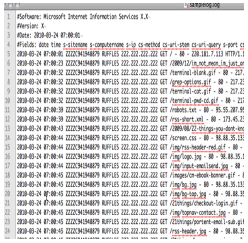
Intended to make important features more salient

Design Engineers
Waveforms



Visualizations of raw data

Cyber
Log Files



Raw data

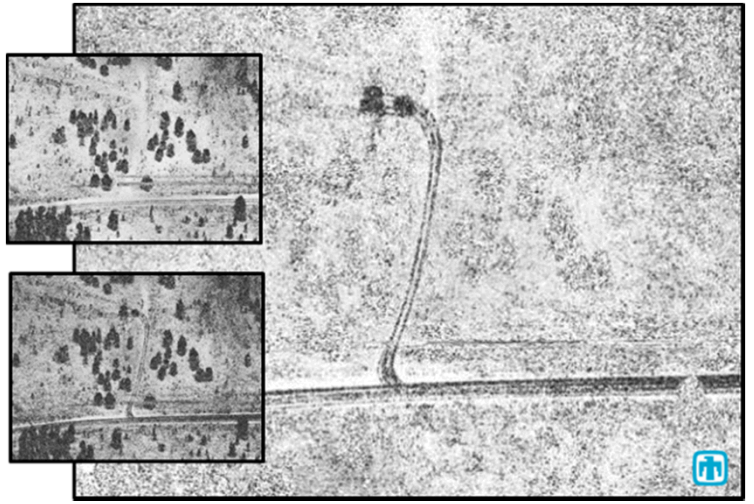
Novices

Experienced with optical imagery only

All participants will complete a battery of domain-general tasks and a domain-specific tasks

A Case Study: Synthetic Aperture Radar (SAR) Imagery Analysis

- SAR analysts recognize and classify patterns using SAR imagery.
- The same scene is repeatedly imaged over extended periods of time, allowing the analyst to see changes.



Courtesy of Sandia National Laboratories, Airborne ISR

Study Details

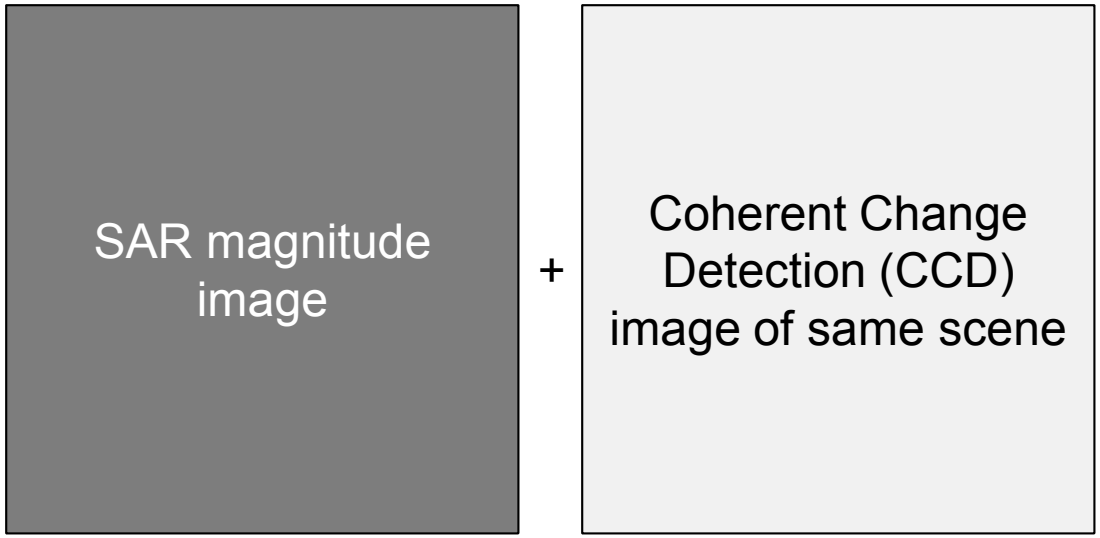
- Participants
  - 8 SAR imagery analysts
  - 8 engineers experienced with the domain (“knowledgeable non-analysts”)
  - 8 SAR novices

- All participants completed domain-specific and domain-general tasks

- Data collected for all tasks:
  - Reaction time
  - Accuracy

Domain-Specific Task: SAR

- Target detection task using two images, presented side by side
  - 50% prevalence of targets
  - Participants rate images on 1-4 scale
    - sure no, unsure no, unsure yes, sure yes



Domain-General Tasks

- Parallel vs. Serial Visual Search
- Visual Inspection Task
- Spatial working memory, Mental rotation, Useful field of view

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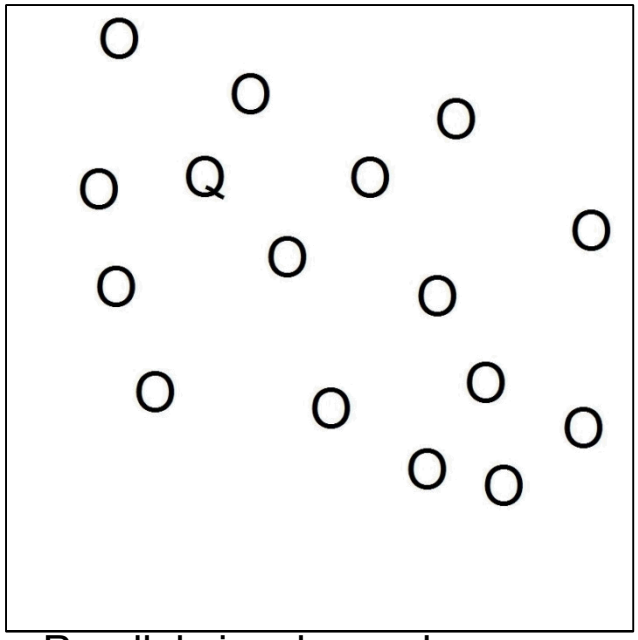
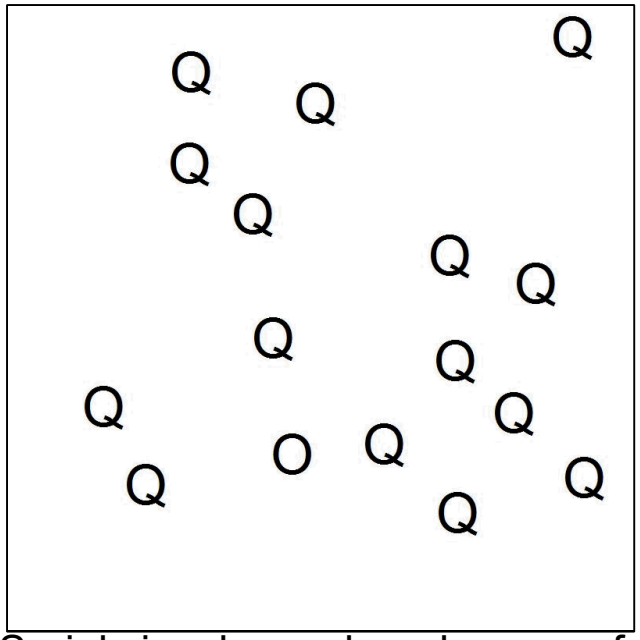


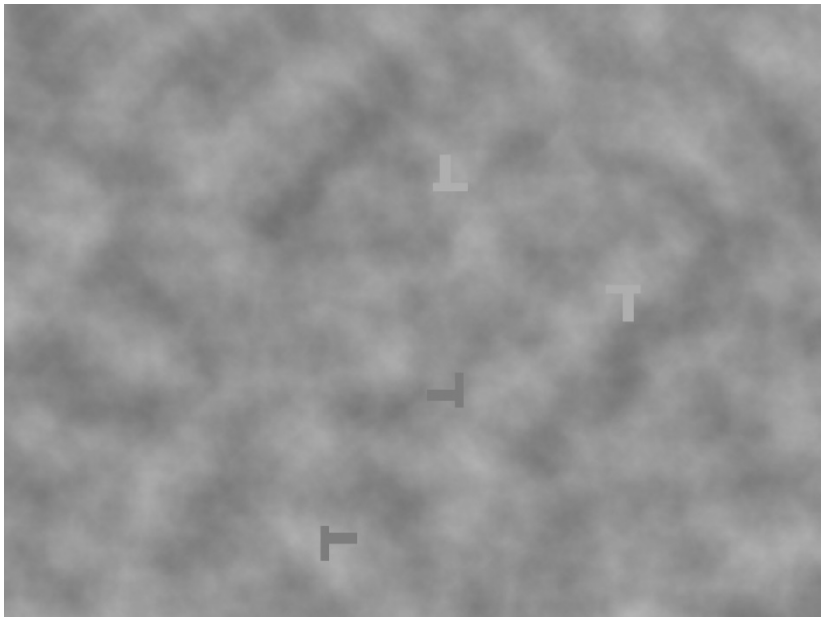
Parallel visual search – unique features “pop out”

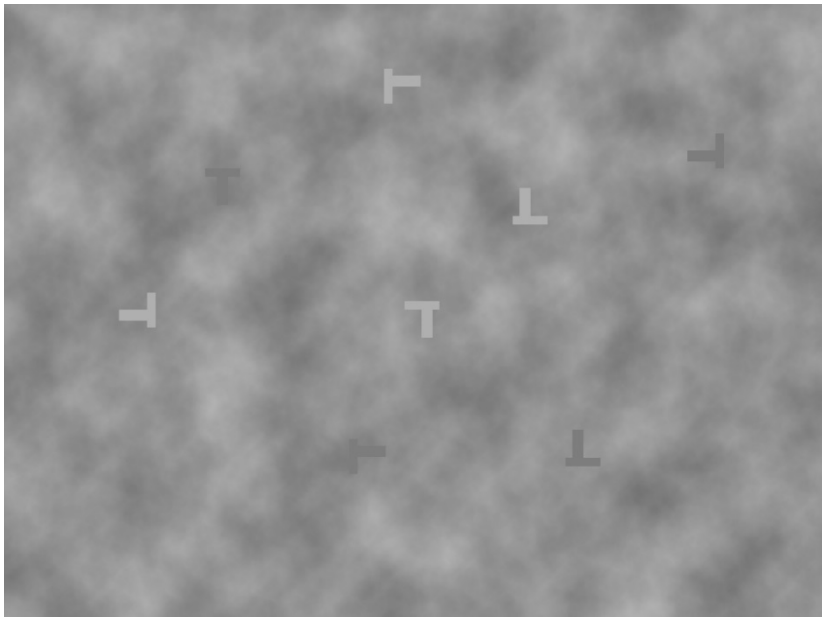


Serial visual search – absence of a feature requires deliberate searching

Domain-General Tasks

- Parallel vs. Serial Visual Search
- Visual Inspection Task
- Spatial working memory, Mental rotation, Useful field of view





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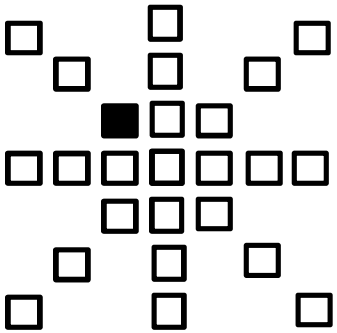
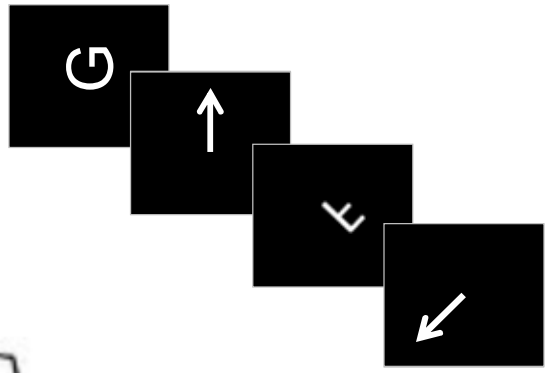
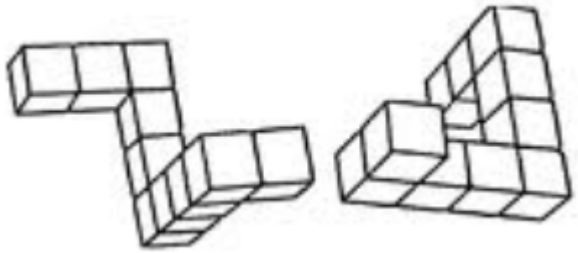
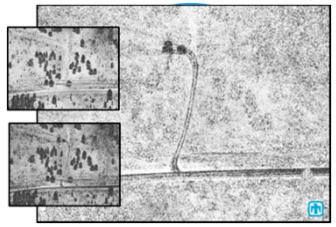
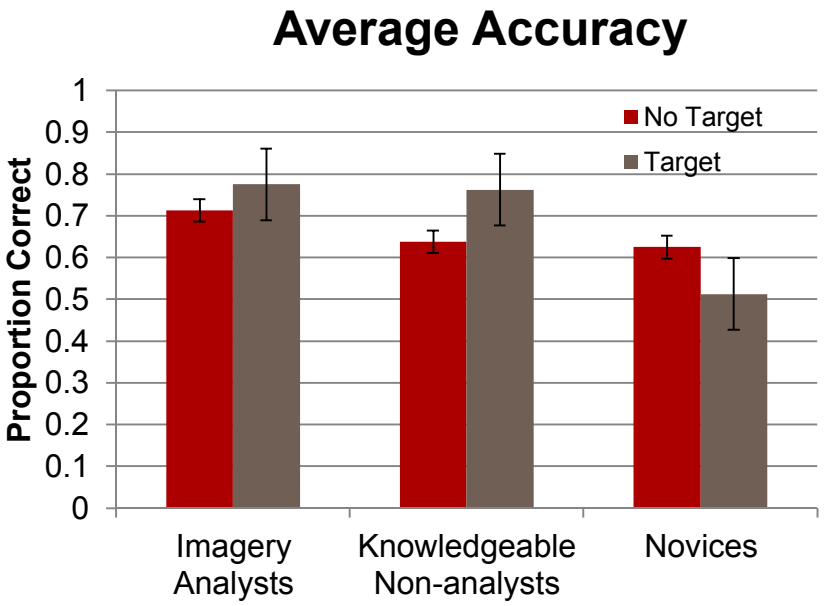


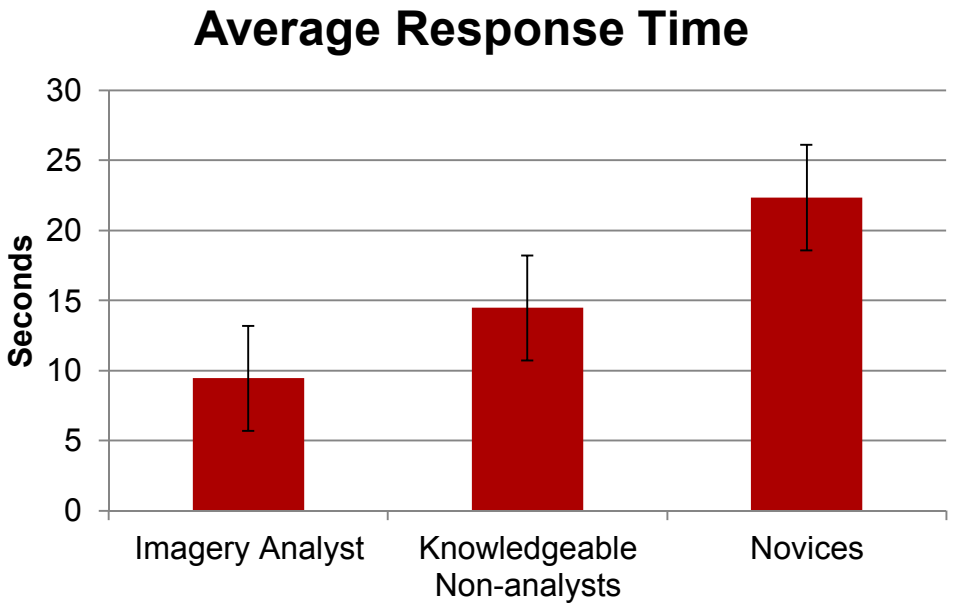




SAR Task Results

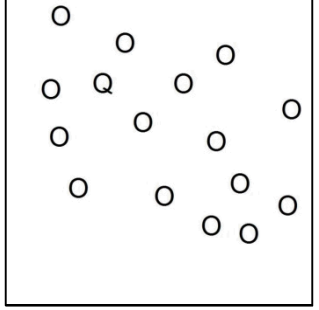


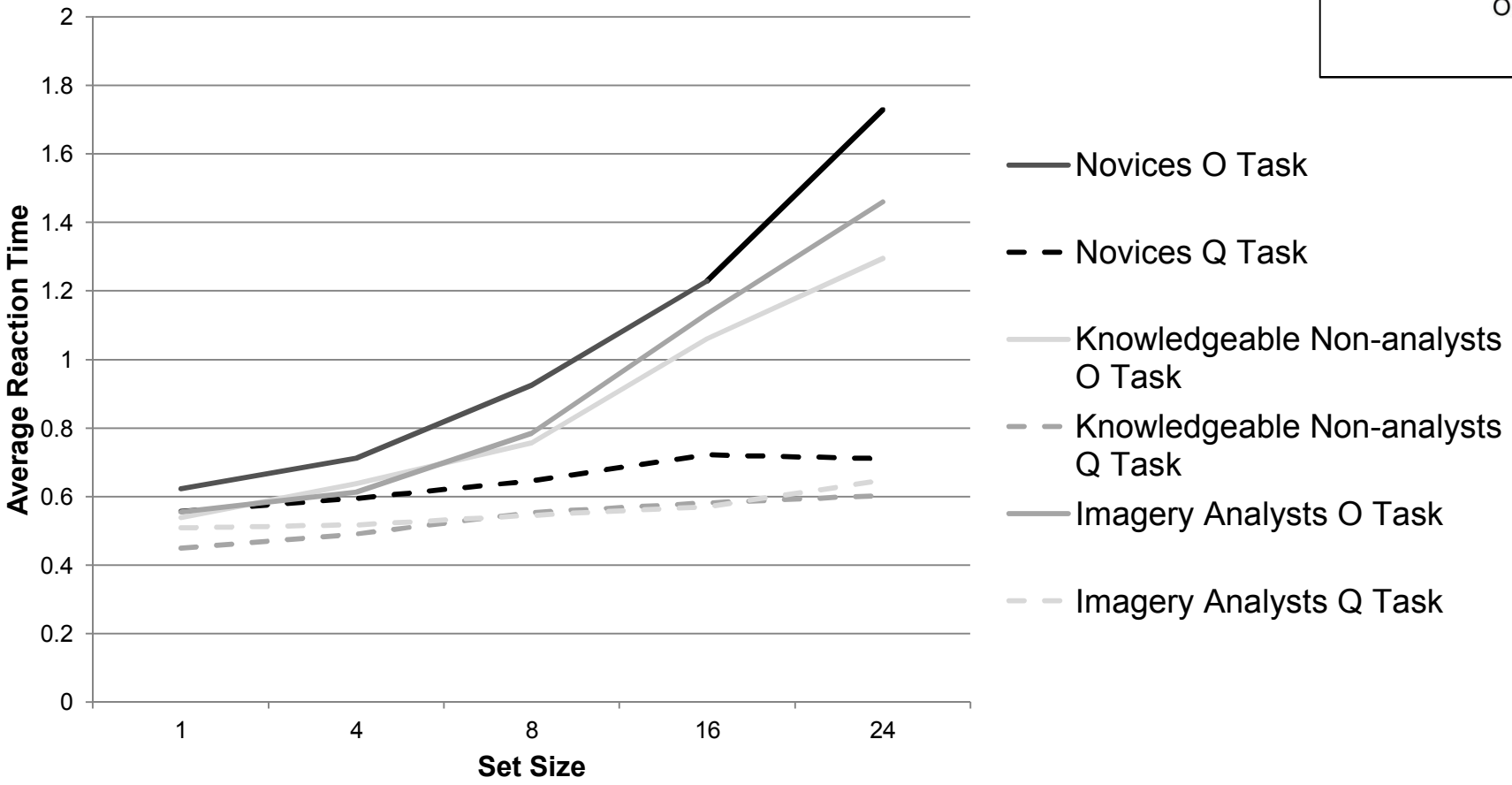




- Imagery analysts and knowledgeable non-analysts were significantly more accurate than the novices.
- Imagery analysts were significantly faster than the knowledgeable non-experts and novices.
- Knowledgeable non-analysts were significantly faster than the novices.

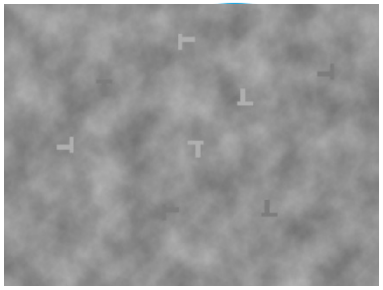
Parallel vs. Serial Search Results

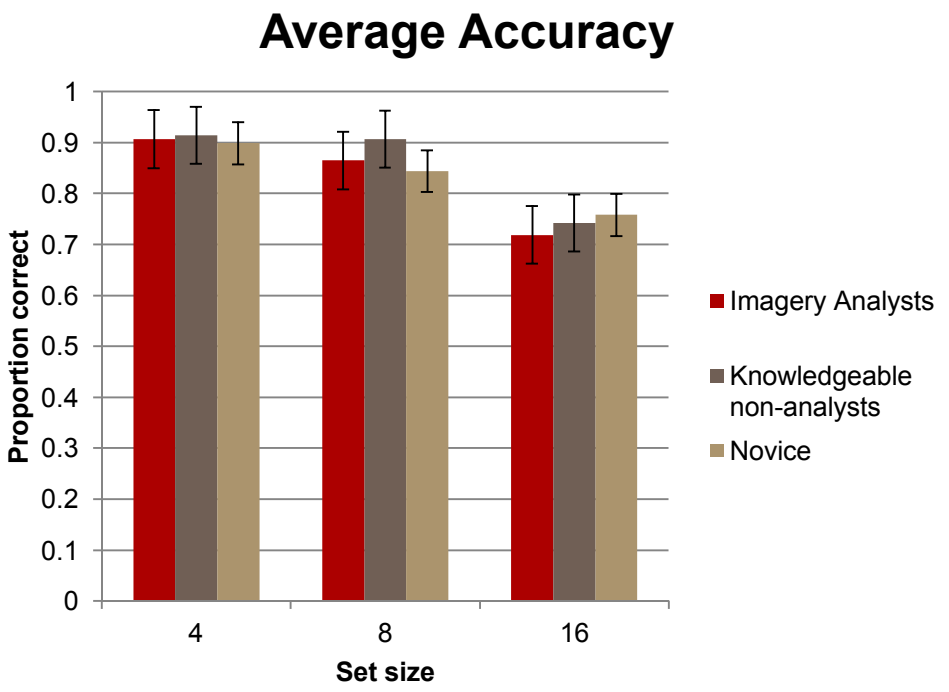


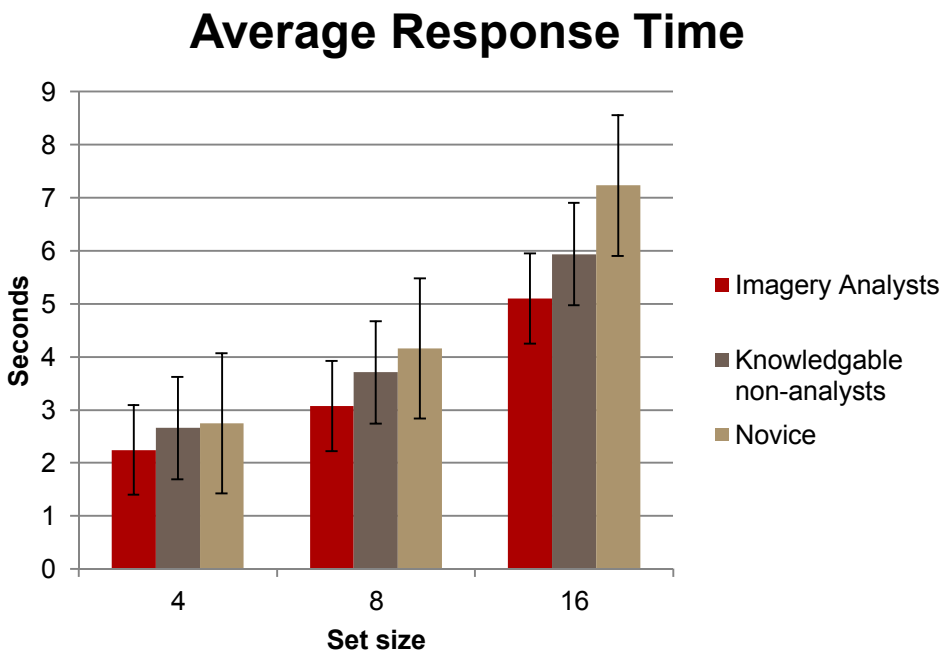


- Novices were significantly slower than the imagery analysts and knowledgeable non-analysts in Parallel Search.

Visual Inspection Task Results





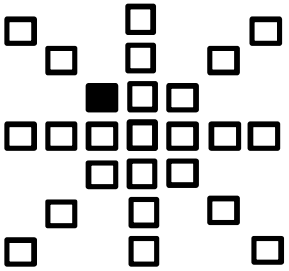


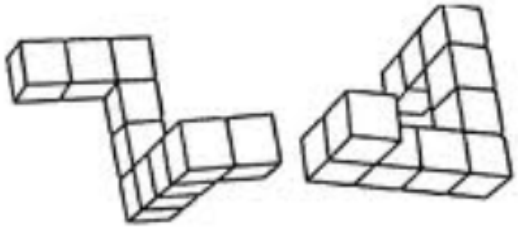
- Imagery analysts were significantly faster than the novices.

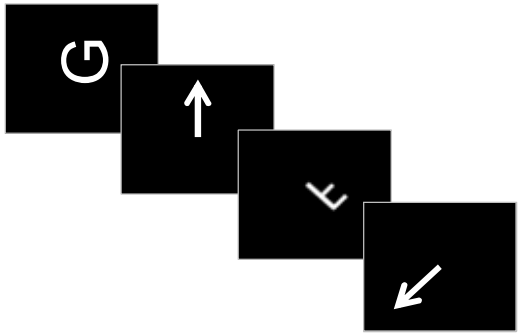
Other Domain-General Task Results

- Mental rotation
- Useful field of view
- Spatial working memory

No significant differences between groups



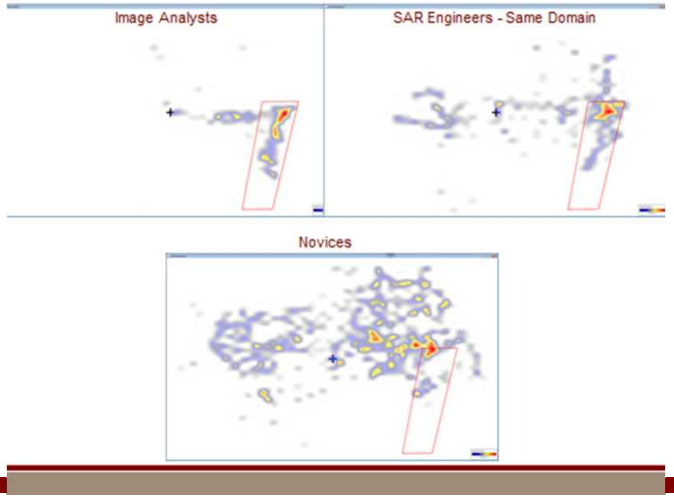




Conclusions and Next Steps

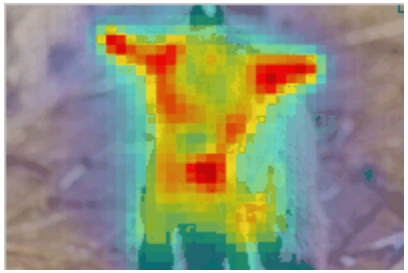
- Novel evidence that professional expertise in visual search influences general visual cognition processes
  - SAR imagery analysts were faster and more accurate on the domain-specific SAR task
  - SAR imagery analysts were faster on the T&L task
  - SAR imagery analysts were faster on the Q pop-out task (surprising!)

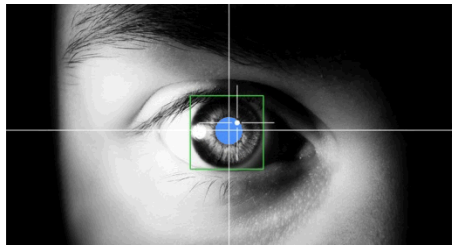
- Aim for development of new methods for analyzing eye tracking data
  - Further data analysis is warranted

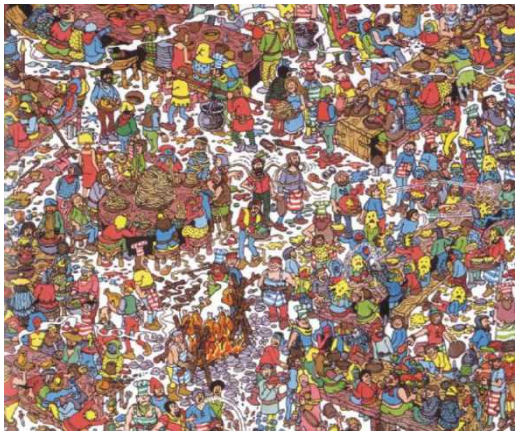


Questions? Thank you!

- Susan Stevens Adams - smsteve@sandia.gov

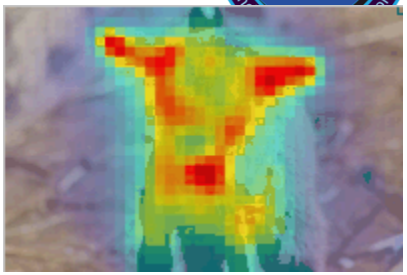




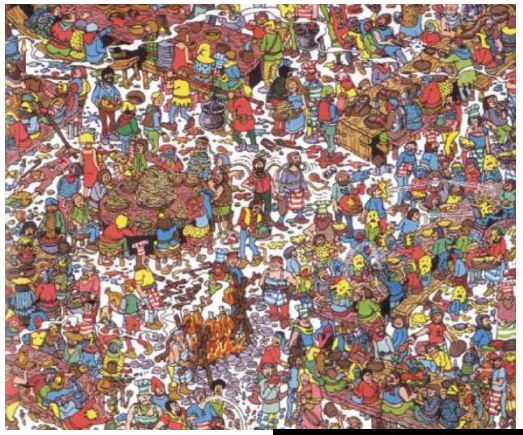


Back-up slides

Visual Attention



- Visual attention has two stages:
  1) Attention is distributed uniformly across a scene
  2) Attention is concentrated to a specific area and information is processed serially (sequential fixations)



- Wolfe's Guided Search Model:
  - Bottom-up *AND* top-down information create a pre-attentive "ranking" of items for attentional priority
  - Feature processing creates an activation map
  - Viewer attends to highest priority item first, then moves down the list

A Key Research Question

- ***Can we model top-down visual saliency for a domain expert performing a particular task?***
  - In other words, can we predict where an expert will look in an image?

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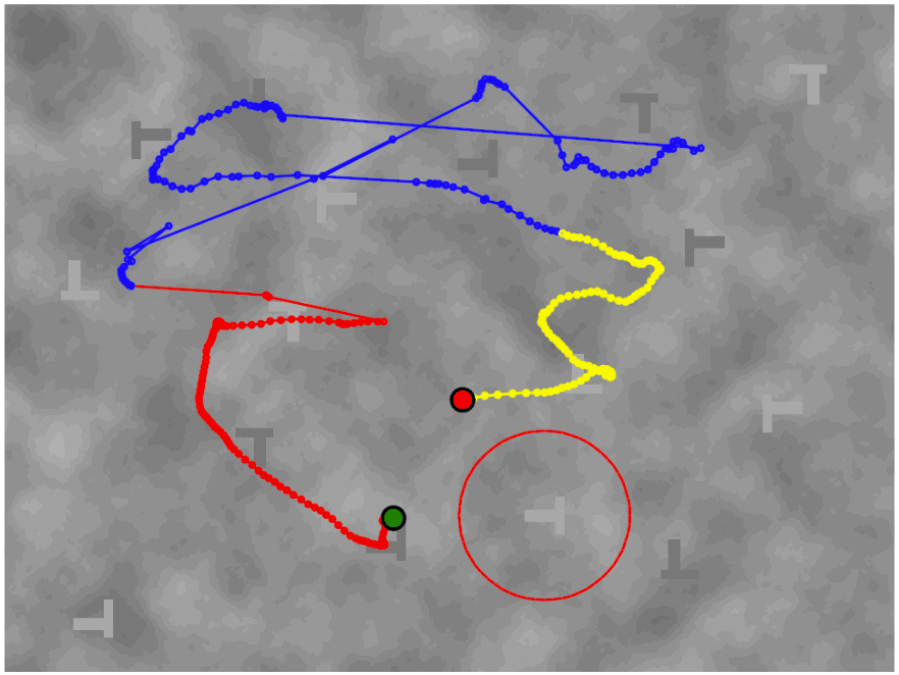
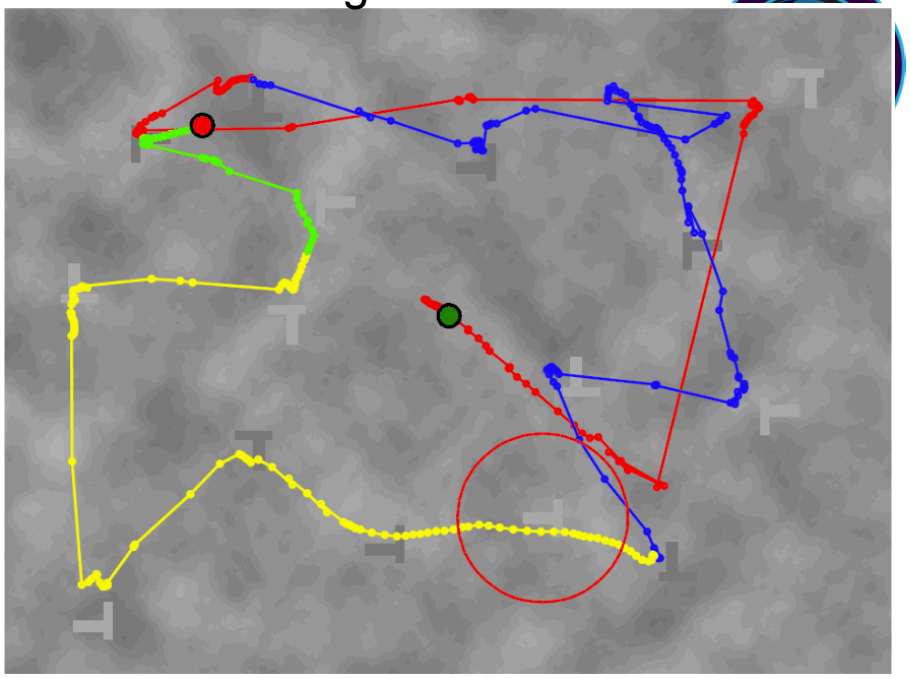
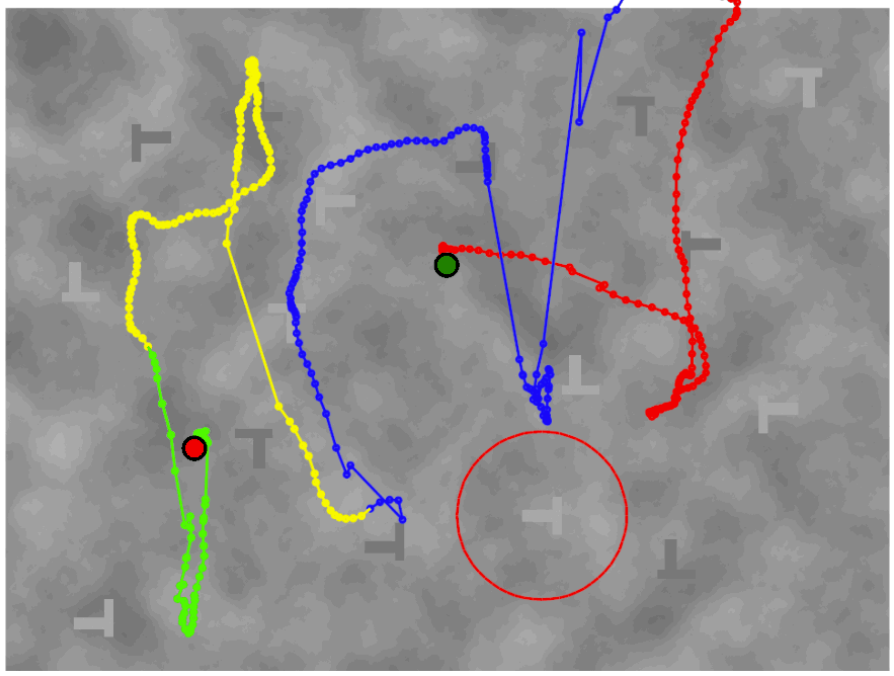
- ***Can we model top-down visual saliency for a domain expert performing a particular task?***
  - In other words, can we predict where an expert will look in an image?

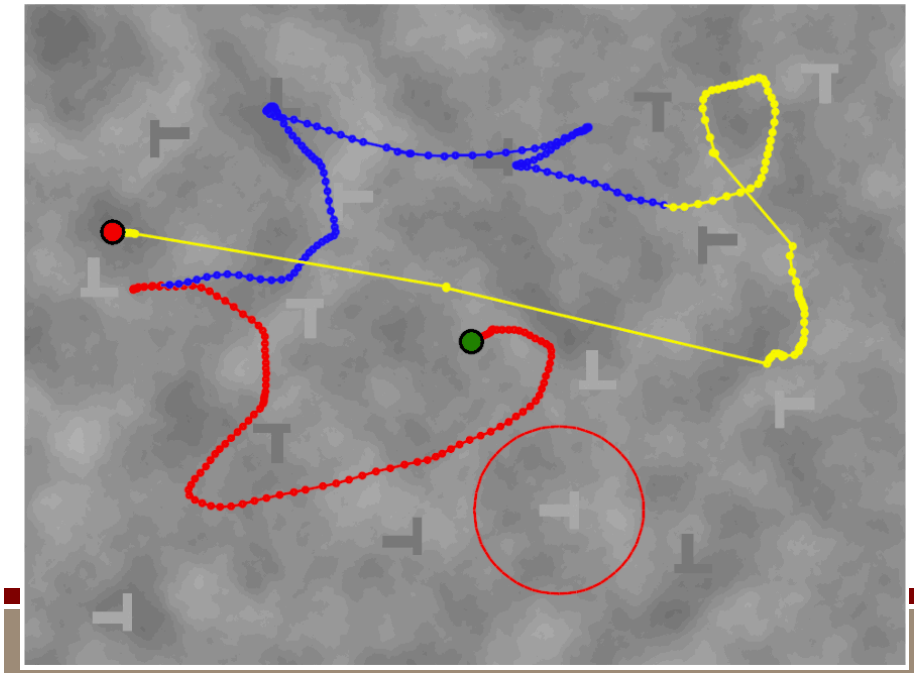
- Why do we care?
  - ***Advances scientific understanding of visual cognition***
    - There are NO models of top-down attention – this is a major gap in the literature
  - ***Numerous applications***
    - Informing system design
      - Top-down model defines user's needs
      - Could identify ways to offload user's working memory load
    - Evaluating new designs
    - Identifying potential sources of error – What is likely to be missed?
    - Training new users

Search Patterns – Who found the target?

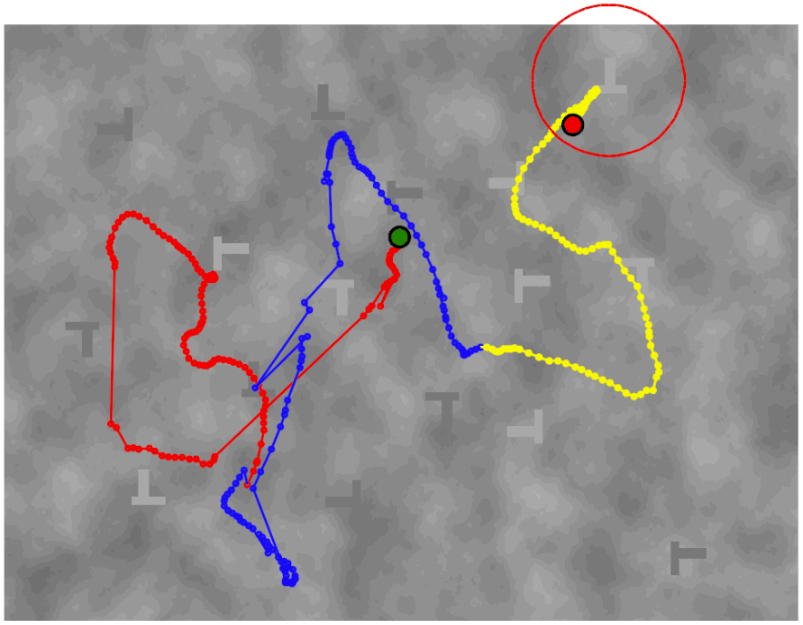






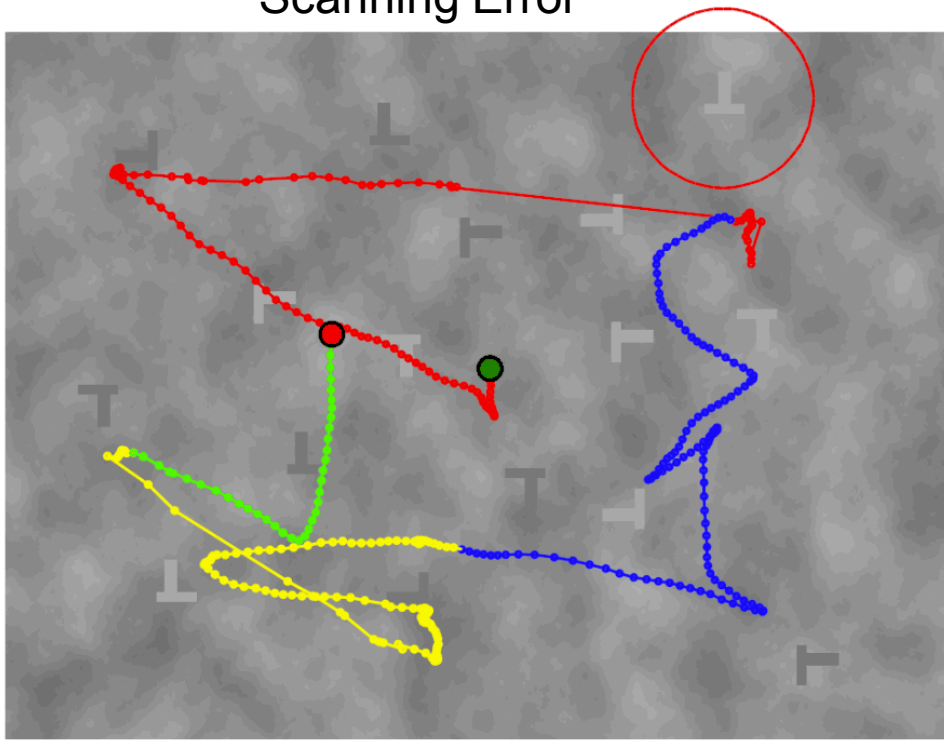


Classification of Error Types

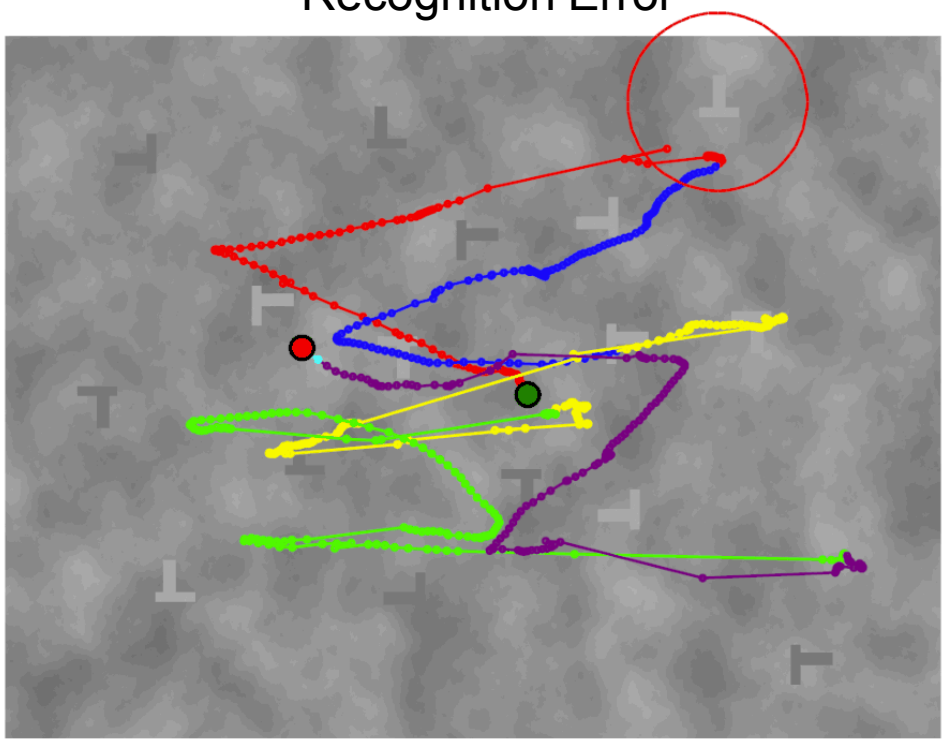


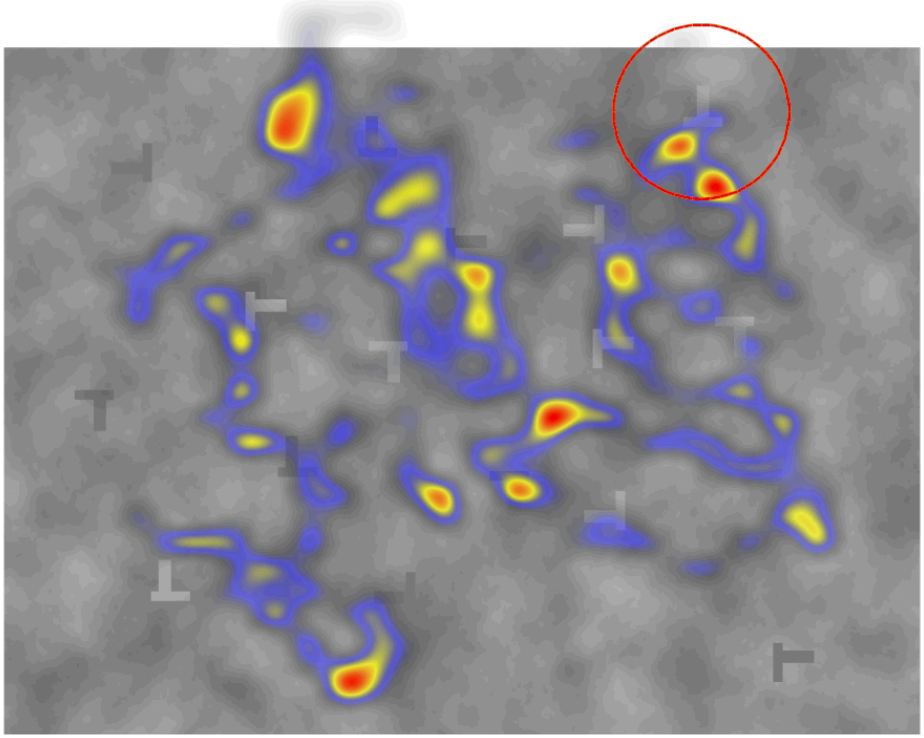
Correct identification of target

Scanning Error

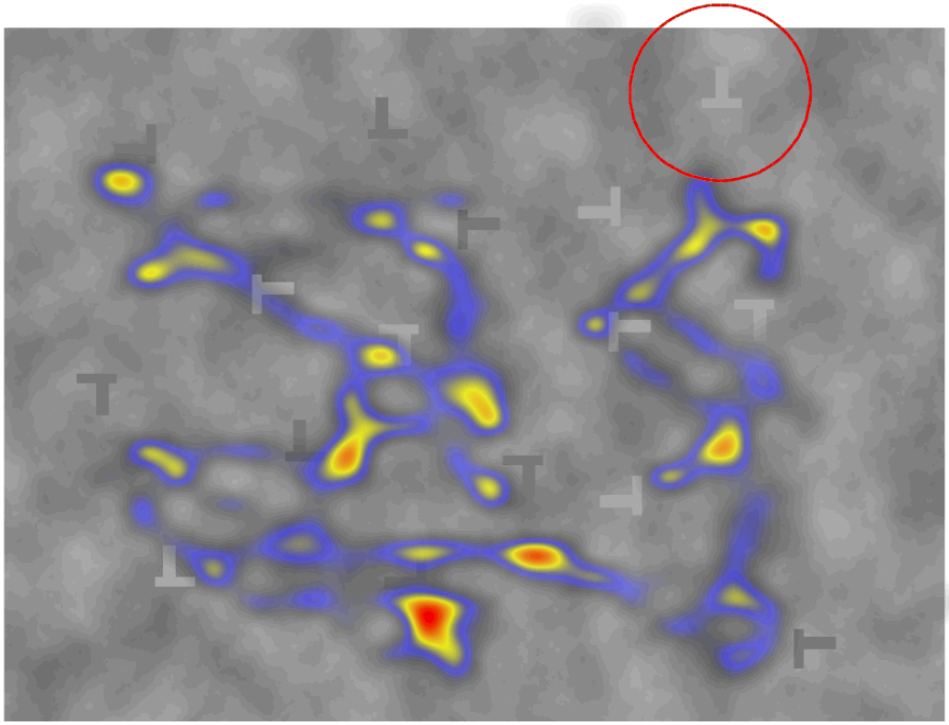


Recognition Error



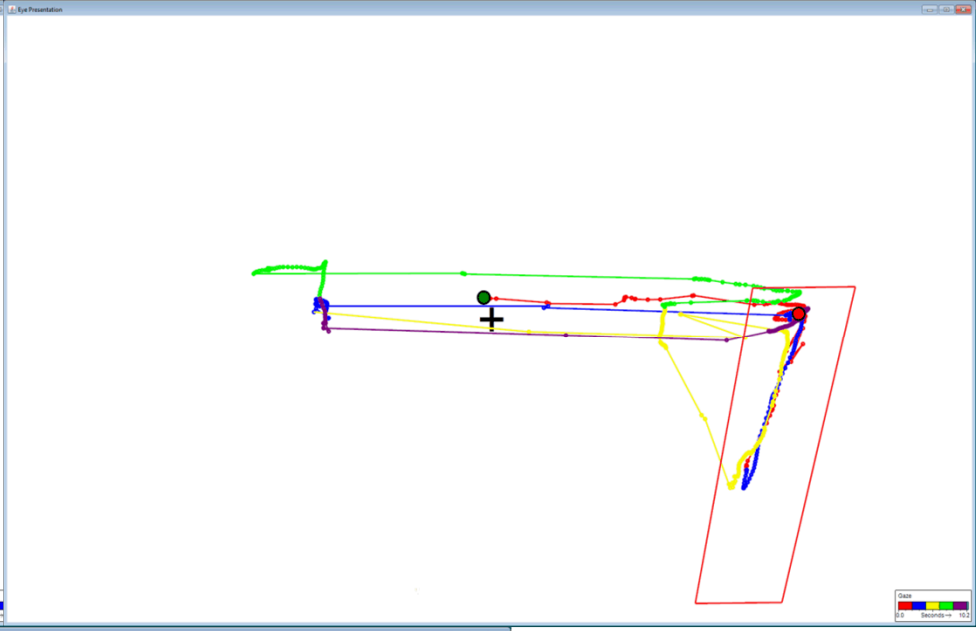


Correct



Incorrect


Eye Presentation
Gaze
0.0 Seconds


Eye Presentation
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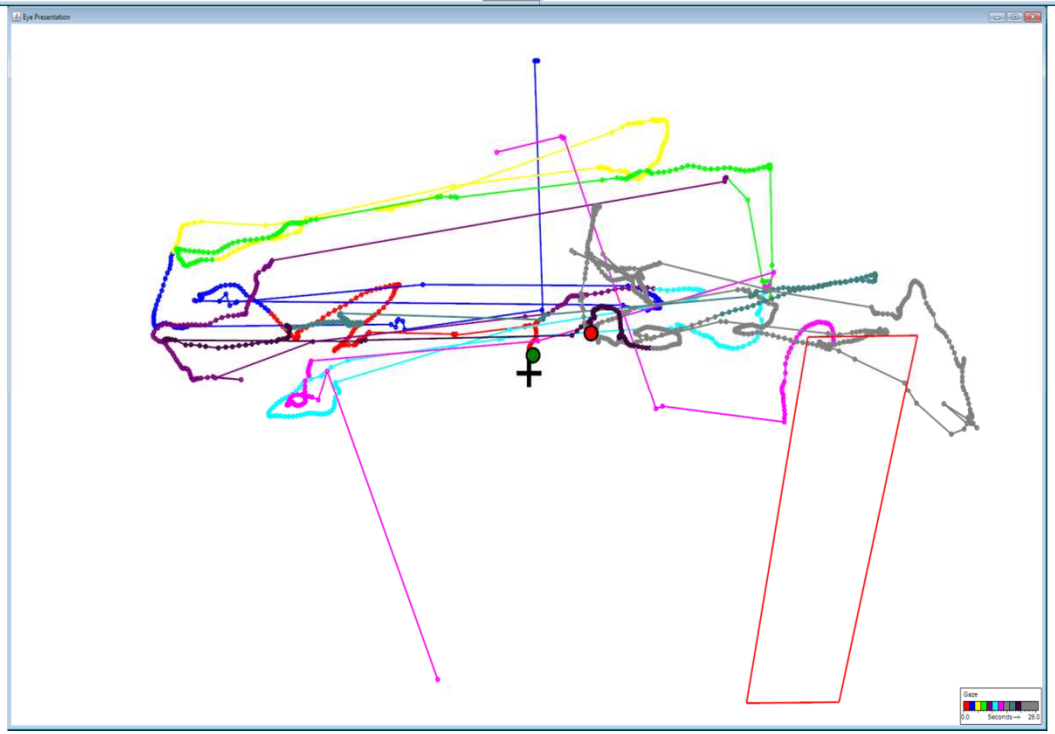
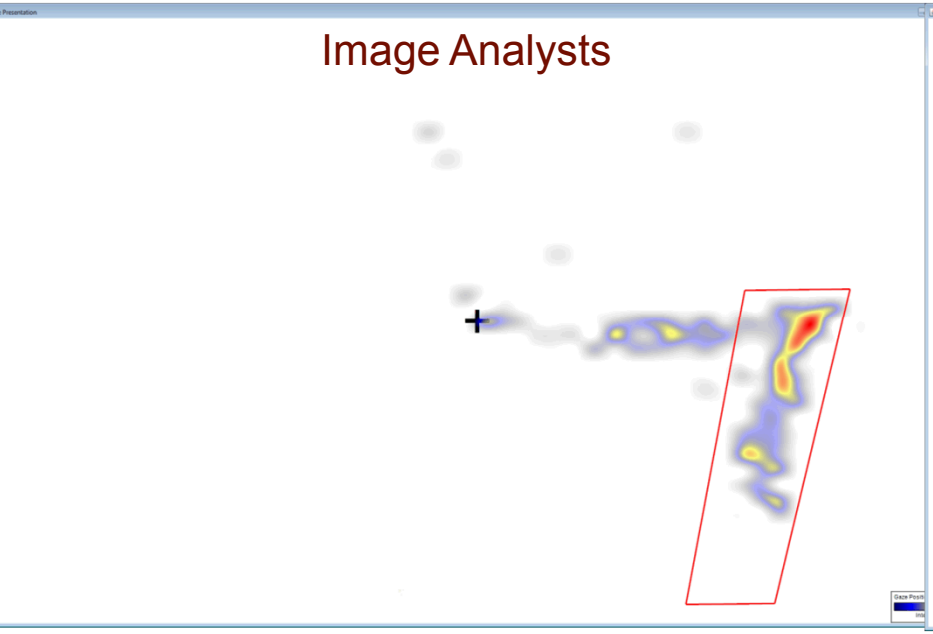
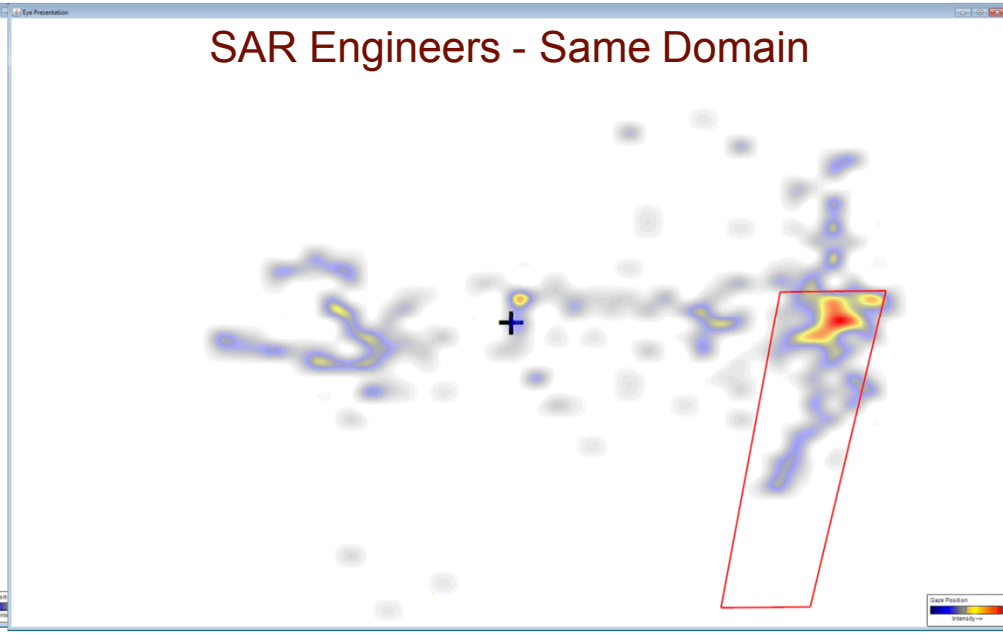

Eye Presentation
Gaze
0.0 Seconds 28.0

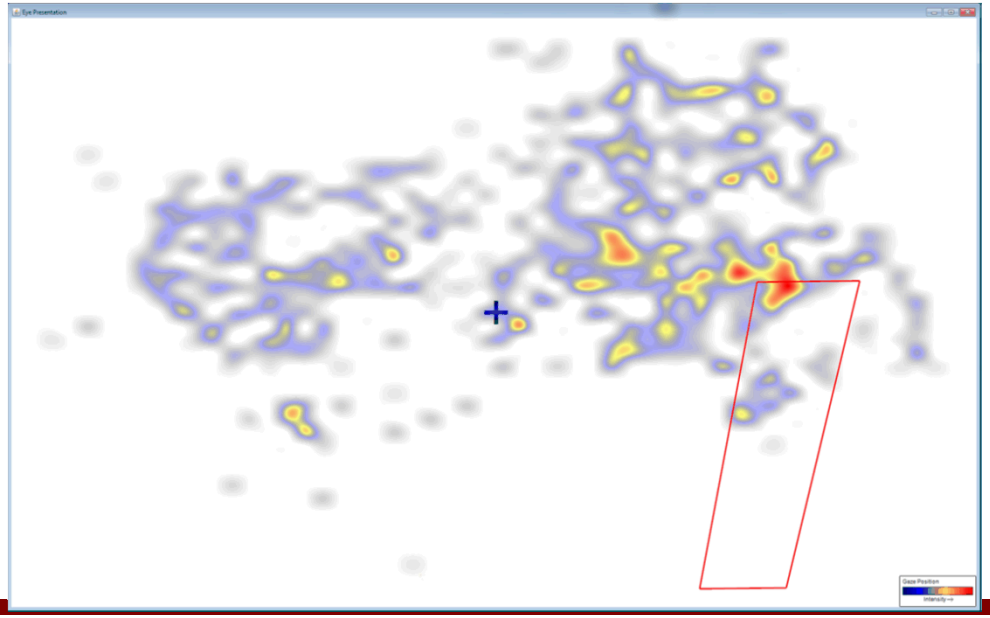
Image Analysts



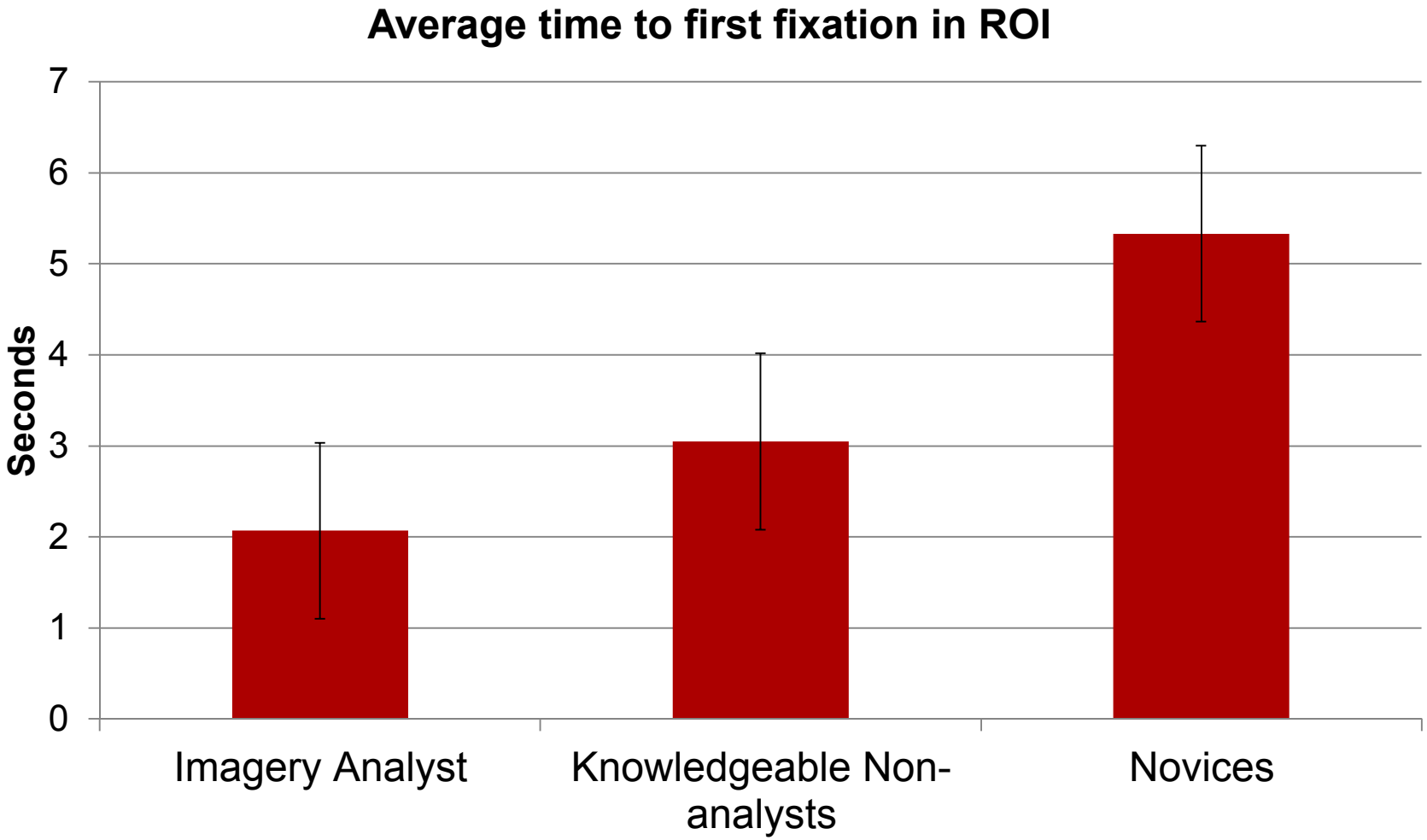
SAR Engineers - Same Domain



Novices



SAR Task - Eye Tracking Results



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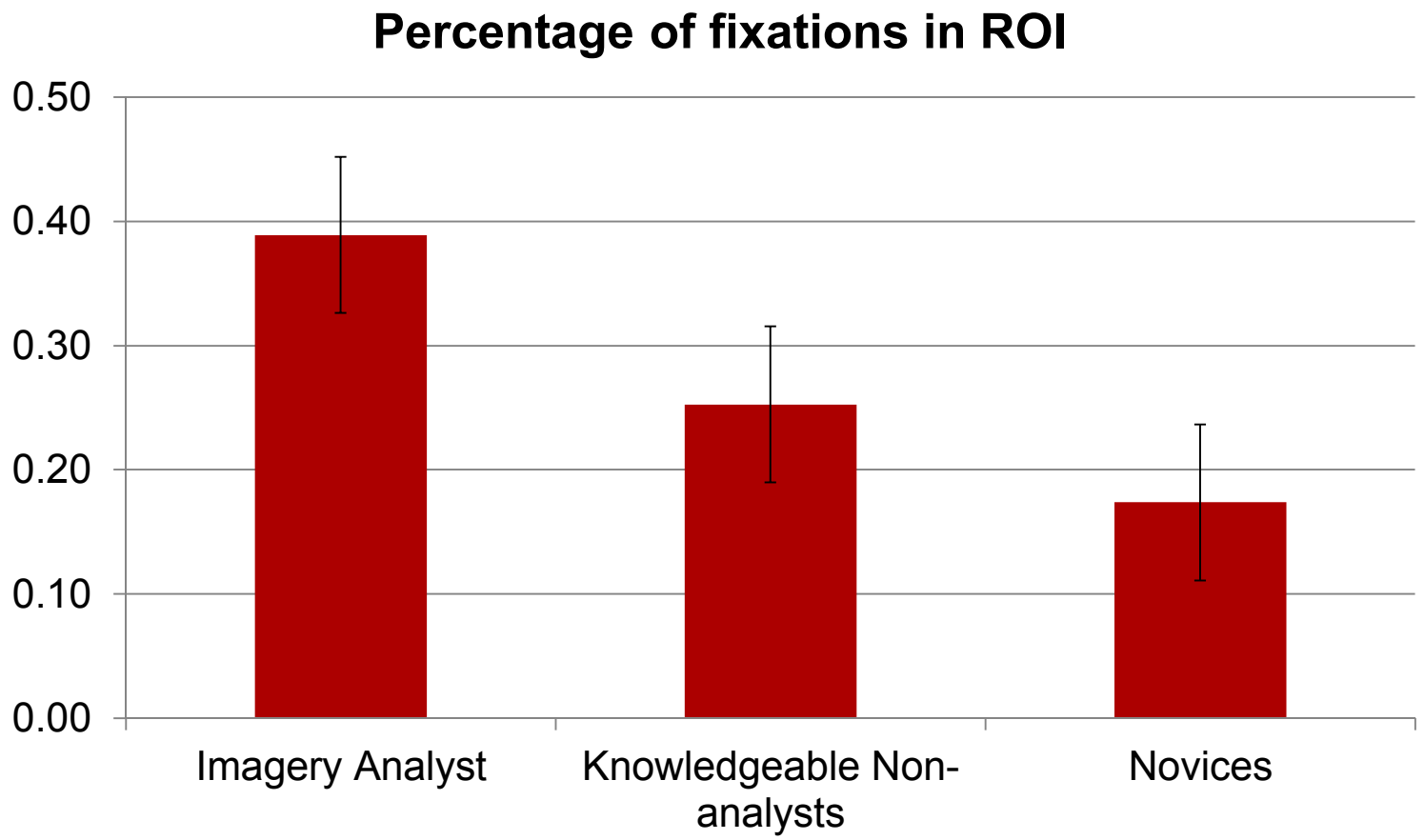
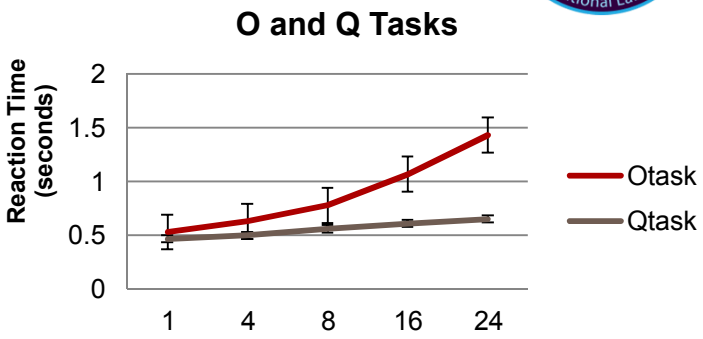
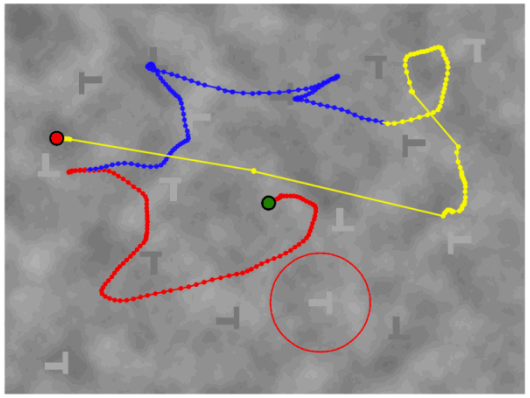
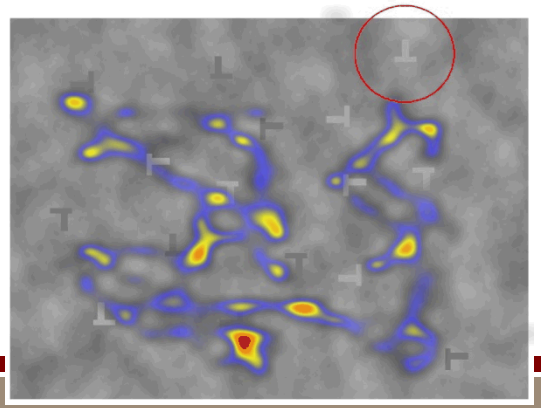


Data Acquired

- Behavioral
  - Reaction time
  - Accuracy
- Eye Tracking
  - Quantitative:
    - Time to first fixation in region of interest (ROI)
    - Percentage of fixations in ROIs
    - Counts and frequencies of transitions between ROIs
    - Classification of error types (scanning error, recognition error, decision error)
  - Qualitative:
    - Characterization of scan paths
    - Characterization of search strategies
    - Identification of features with high top-down saliency
  - New approaches:
    - Contrasting bottom-up saliency maps with recorded gaze patterns
    - Modeling influence of top-down saliency
    - Trajectory analysis

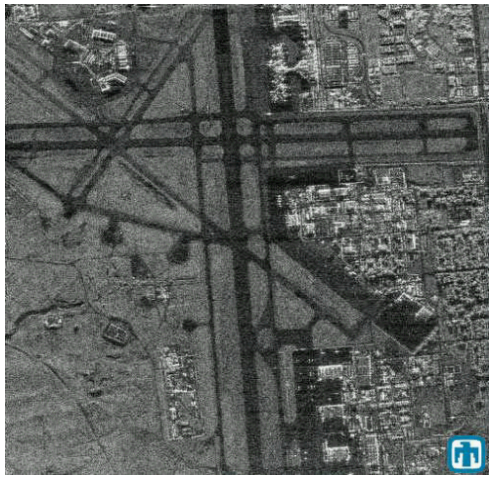






Synthetic Aperture Radar (SAR)

- Our IA's recognize and classify patterns using SAR imagery
  - SAR - repeatedly image same scene over extended periods of time.

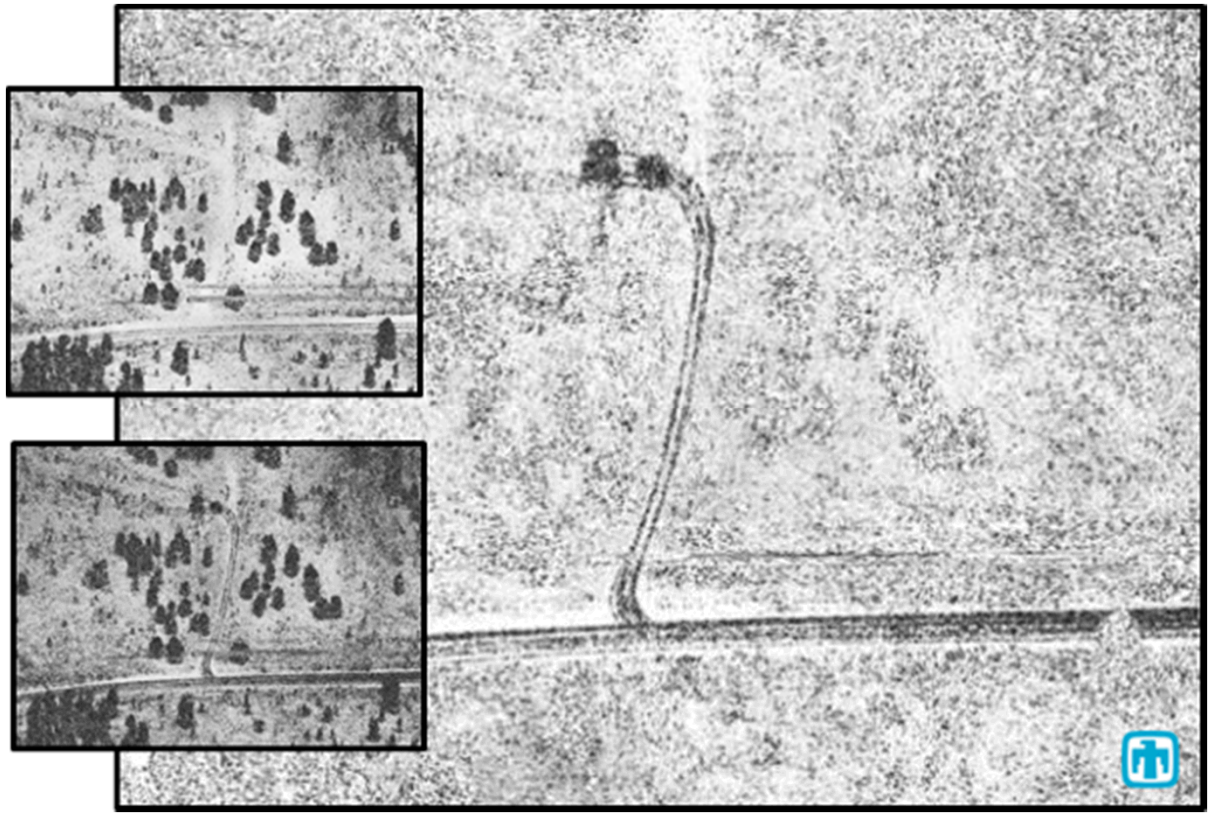


- Our focus is on "off-line" analysis
  - IA's determine what happened after the fact
  - Make decisions by reading text reports, looking through PowerPoint presentations and scanning SAR imagery

A Case Study: Synthetic Aperture Radar Imagery Analysis

Courtesy of Sandia National Laboratories, Airborne ISR

A Case Study: Synthetic Aperture Radar Imagery Analysis



Courtesy of Sandia National Laboratories, Airborne ISR

Domain-specific task: Synthetic Aperture Radar (SAR)

- Target detection task using two images, presented side by side
  - 50% prevalence of targets
  - Participants rate images on 1-4 scale
    - sure no, unsure no, unsure yes, sure yes