Cognitive Strategies and Eye Movements for Searching Hierarchical Displays

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Three Main Points

- A **hierarchical display** motivates specific patterns of perceptual, cognitive, and motor processing.
- **Cognitive modeling** can be used to reveal and explain the cognitive processing and strategies that people use when searching a visual hierarchy.
- **Eye tracking** can be used to evaluate, validate, and refine cognitive models.

A lack of a visual hierarchy makes it harder to find things

An example of a layout with no visual hierarchy:

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A visual hierarchy aids visual search

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Consortia, Special Areas and CHI Fringe

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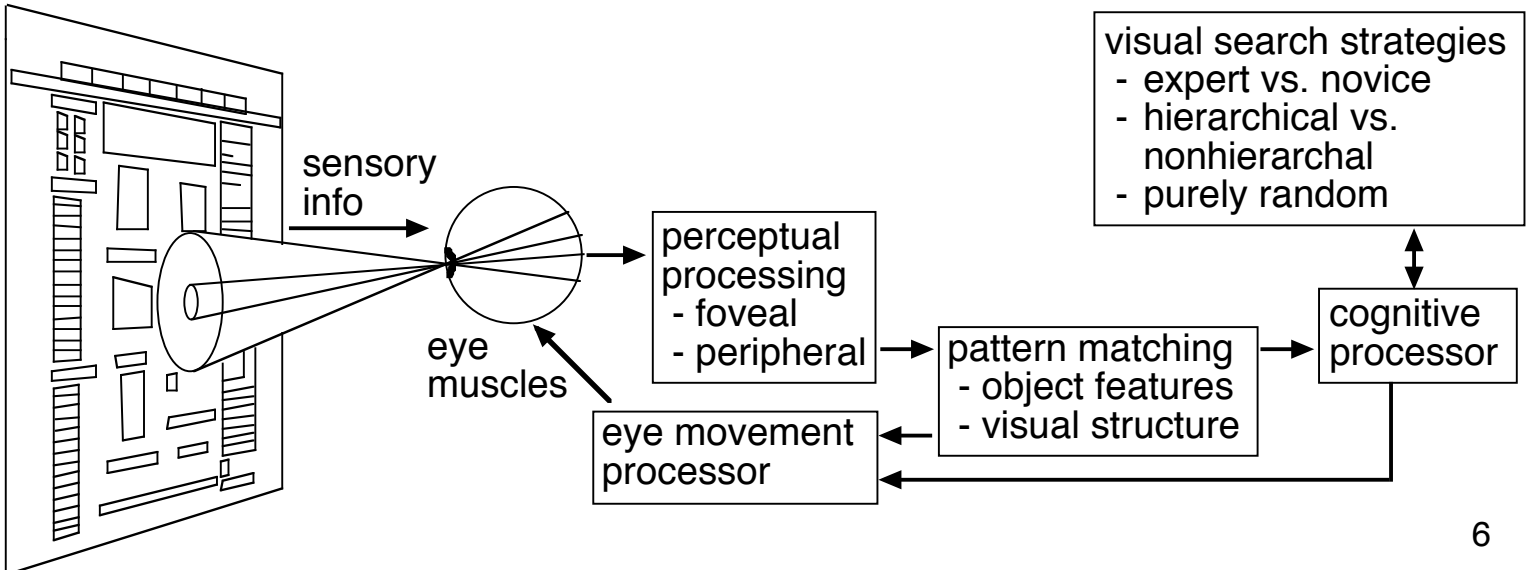
Cognitive modeling in HCI

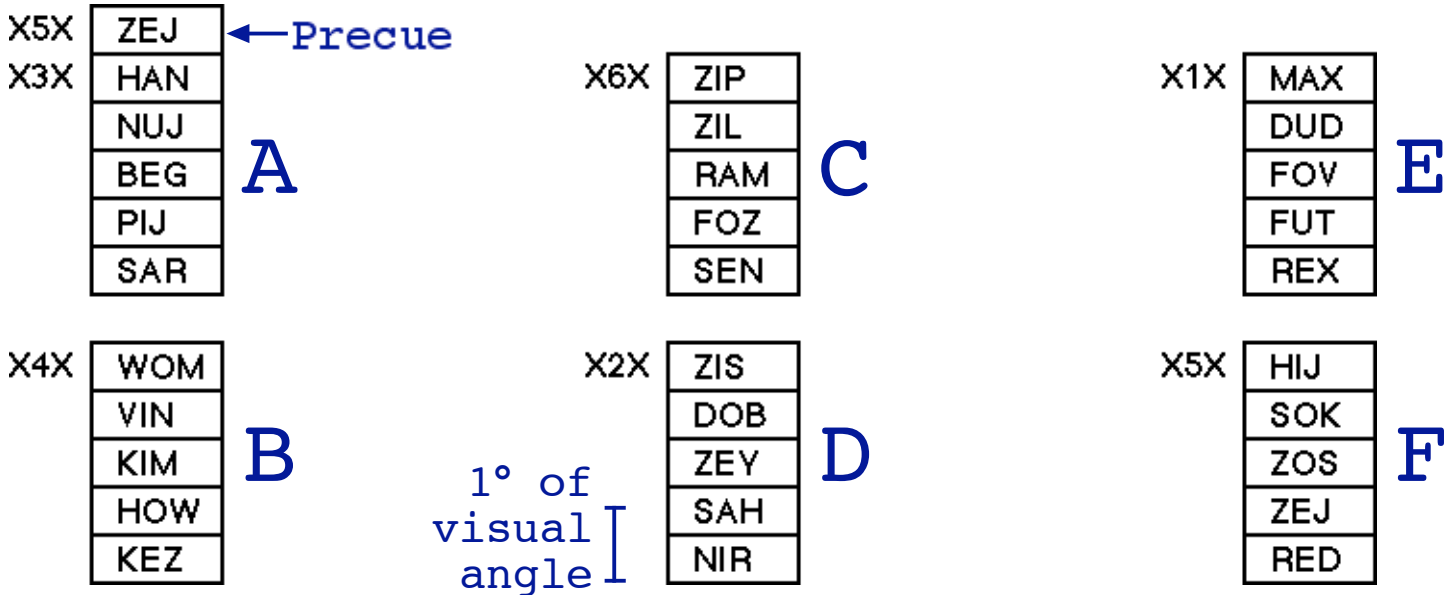
- Two main goals:
  1. Explain user behavior.
  2. Predict user behavior.
- Simulates perceptual-motor processes and cognitive strategies.
- A generic cognitive architecture for visual search:



The EPIC Cognitive Architecture

- EPIC: Executive Process-Interactive Control
- Kieras and Meyer (1997)
- Captures human perceptual, cognitive, and motor processing into a simulation framework
- Constrains the models that can be built
- Inputs into the architecture:
  - Task environment
  - Visual-perceptual features
  - Cognitive strategies
- Outputs from the running model:
  - Execution times
  - Trace of the processing
  - Eye movements

The Experimental Task



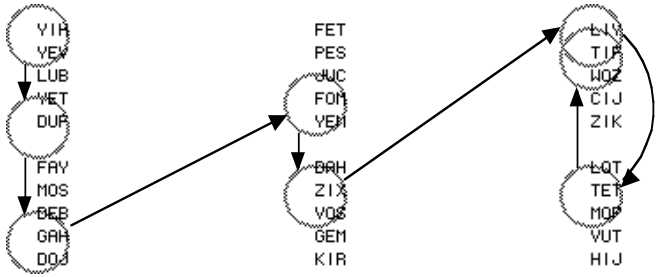
Experimental Design

- 2 x 3 design. Layouts were labeled or unlabeled. Layouts had 2, 4, or 6 groups. Blocked by layout type.
- Procedure: Study precue, click on precue, find target, click on target.
- 16 participants, motivated to search quickly
- Search and selection time recorded separately

Two search strategies

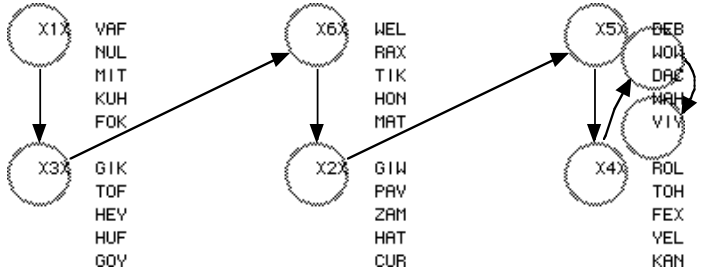
Unlabeled

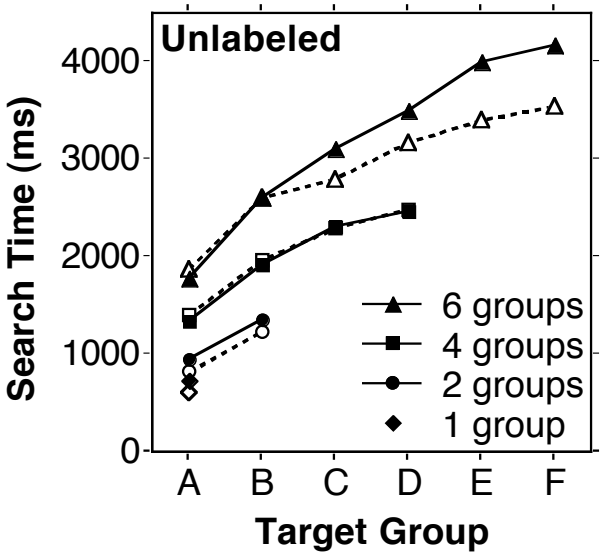
Noisy-systematic search



Labeled

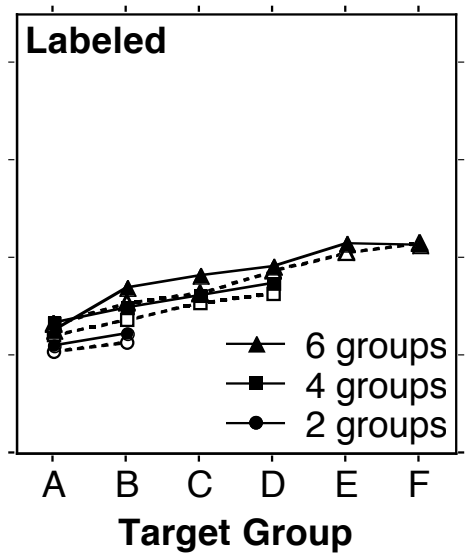
Two-tiered search strategy





Observed

Predicted



Eye Tracking in HCI

Two general uses:

- Input device
- Retrospective analysis

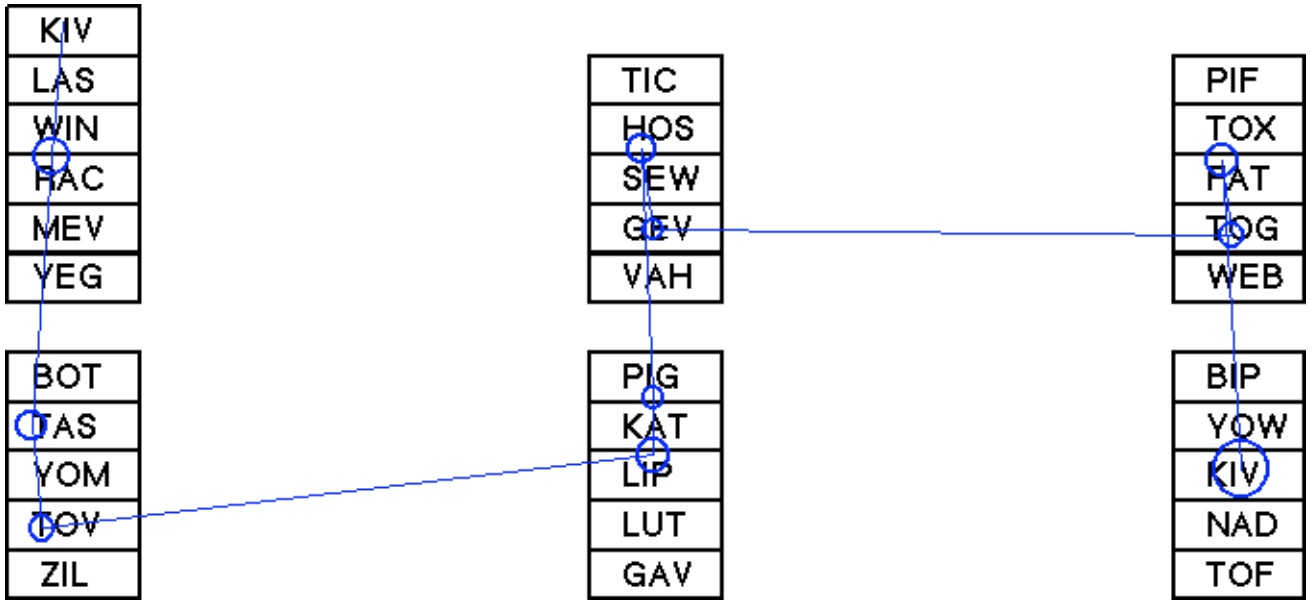
(Jacob and Karn, 2003)

The experiment run with eye tracking

- Identical design, but eye movements were recorded
- LC Technologies Eyegaze System (60 Hz, pupil-center and corneal-reflection)
- Dispersion-based fixation identification (minimum fixation 100 ms, deviation threshold 0.5° visual angle)
- Cleaned up data using *required fixation locations* (Hornof and Halverson, 2002)

Eye movements for a couple trials

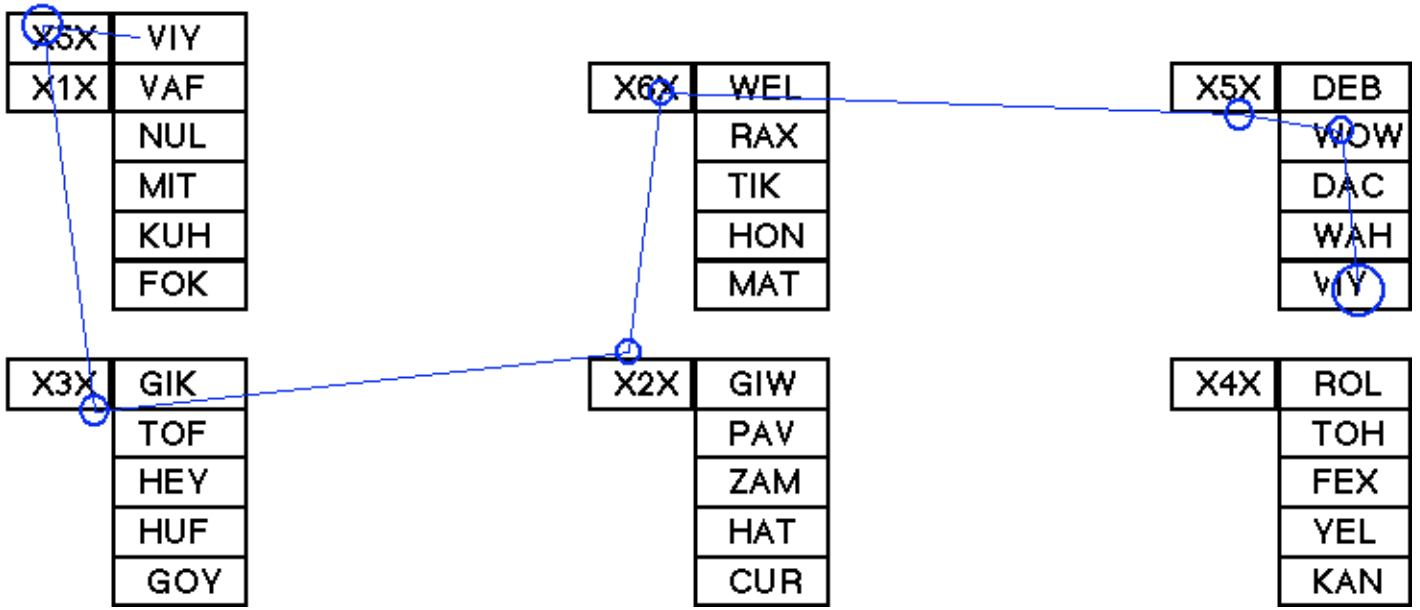
Unlabeled Layout



Visualized with VizFix (Google search on “VizFix”)

Eye movements for a couple trials

Labeled Layout



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Eye movements

Across All Layouts	**Observed**	**Predicted**
Fixations per trial (+)	7.4	7.9
Fixation duration (+)	264 ms	228 ms
Number of scan paths	Many	One
Anticipatory fixations (+)	Yes	Yes
Respond to layout onset (+)	Yes	Yes
Ignore white space (+)	Yes	Yes
Ignore text shape (+)	Yes	Yes
Overshoot the target	Rarely	Yes
Unlabeled Layouts		
Fixations per group	2.1	1.1
Groups revisited per trial	0.69	4.4
Items examined per fixation (+)	2.4	2.6
Labeled Layouts		
Use group labels (+)	Yes	Yes
Groups revisited per trial	0.29	1.2

Eye movements

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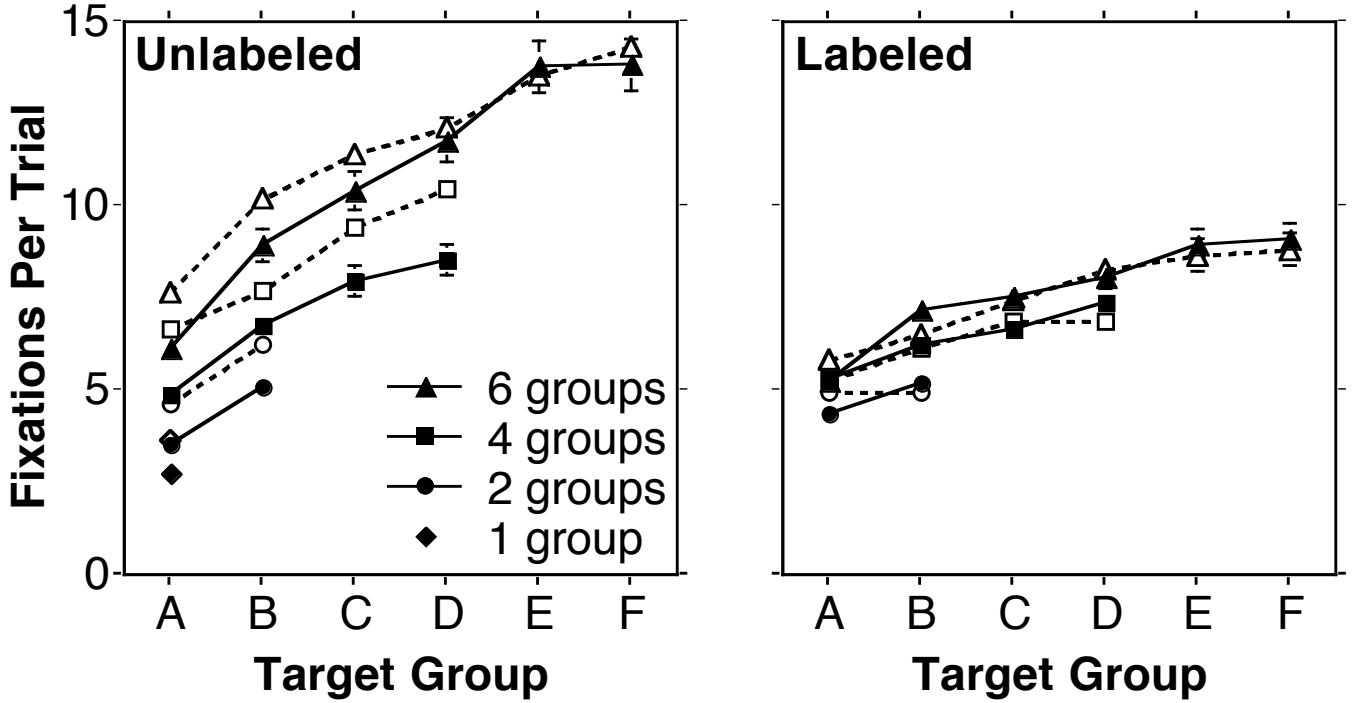
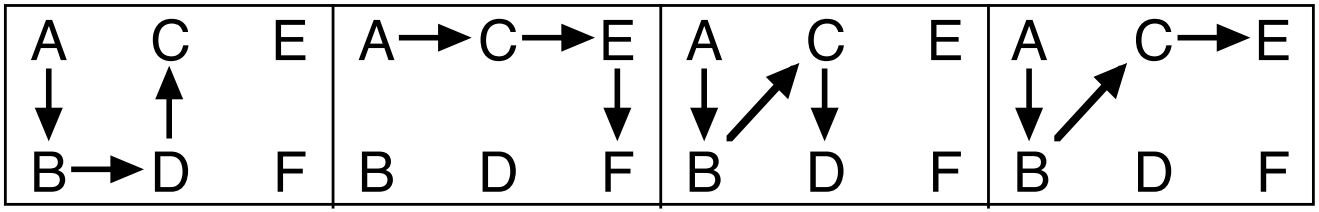
Fixations Per Trial



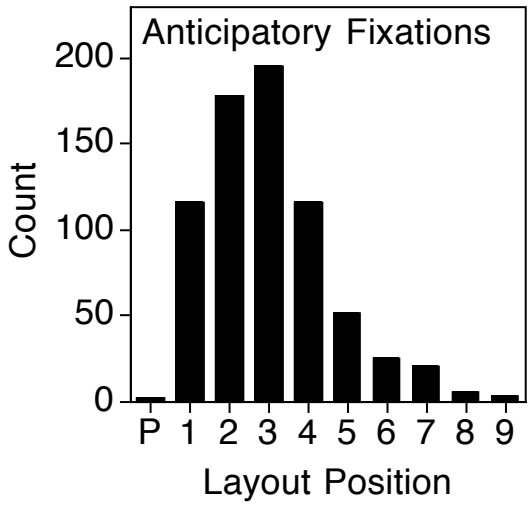
Scan Paths



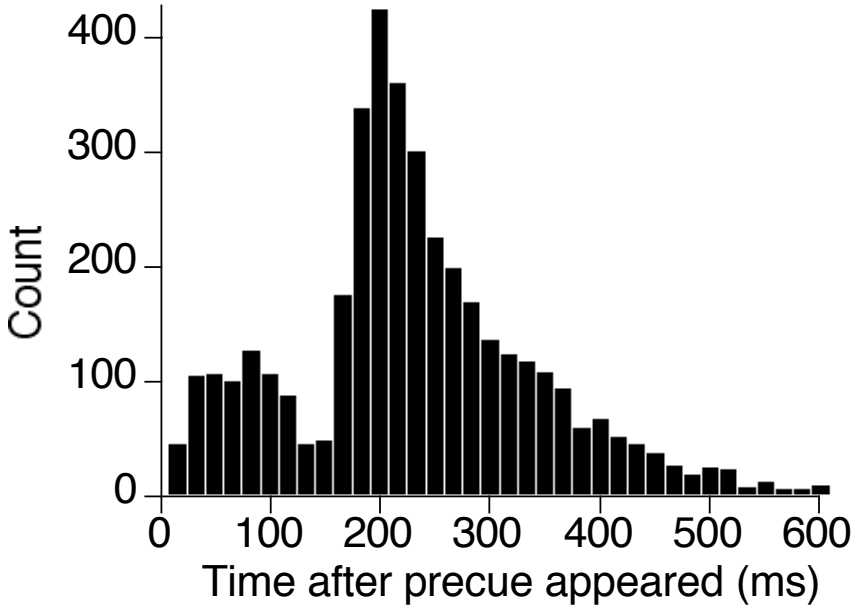
Observed				
Unlabeled:	**30%**	**12%**	**17%**	5%
Labeled:	**19%**	**12%**	6%	7%
Predicted				
Unlabeled:	0%	1%	**70%**	**12%**
Labeled:	0%	0%	**75%**	0%

How People Started the Search

Anticipatory Fixations



Second Fixations
Respond to layout onset



Eye Movements

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What Have We Learned About...

- Hierarchical Displays
- Cognitive Modeling
- Eye Tracking

Hierarchical Displays

Patterns of Behavior	Design Recommendations
Use a visual hierarchy	Support a multitiered search
Examine multiple items with a single fixation	Facilitate simultaneous foveal coverage
Jump over white space	Use white space
Anticipate visual locations	Provide consistent layouts
Prime for onset	Very fast response times

Cognitive Modeling

- Many aspects of the strategies, models, and architecture appear to be correct:
  - More than one item with each fixation
  - Global search strategies
  - Ignore shape
  - Anticipatory fixations
- The data also identify a number of improvements to made:
  - Wider range of scanpaths
  - Stopping on the target

Eye tracking

- Examines specific details of the models:
  - Strategies
  - Perceptual-motor processes
- Better than open-ended questions such as: "How do people move their eyes in *Task X*?"
- Synergy between eye tracking and modeling
- A good way to proceed:
  - Identify theories established with standard measures (speed, accuracy, clickstreams)
  - Evaluate the theory with eye tracking.

Future Work

- Evaluate aspects of the Cognitive Walkthrough for the Web (Blackmon, et al. 2003) using eye tracking.
- “Give meaning” to cognitive modeling of visual search.
- Predictive visual search tool