Cognitive strategies for visual search

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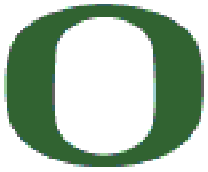

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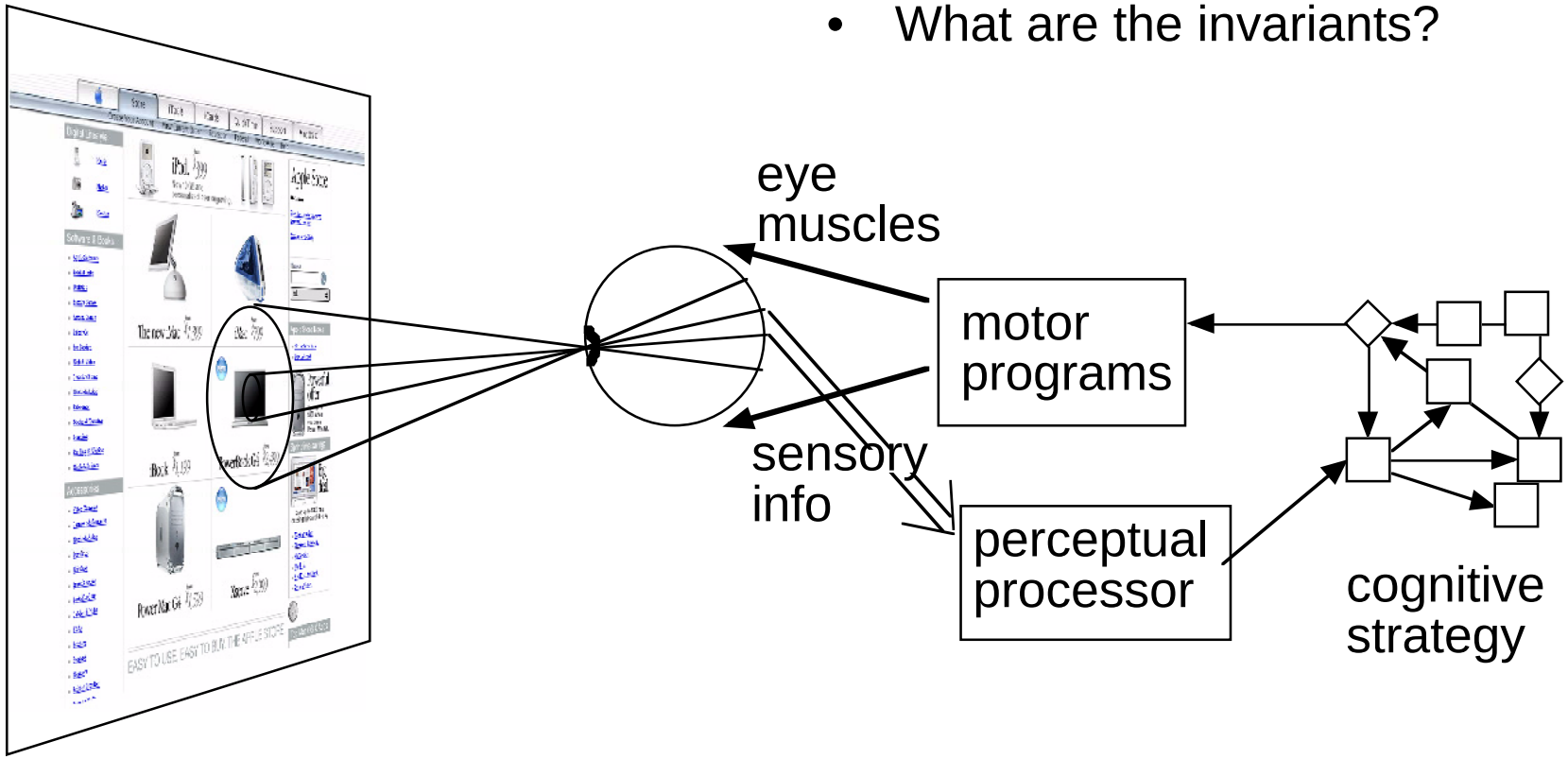
Cognitive strategies coordinate the perceptual and motor processes used to visually navigate a scene or display

http://www.atlanticfleet.navy.mil/tr-catcc.jpg

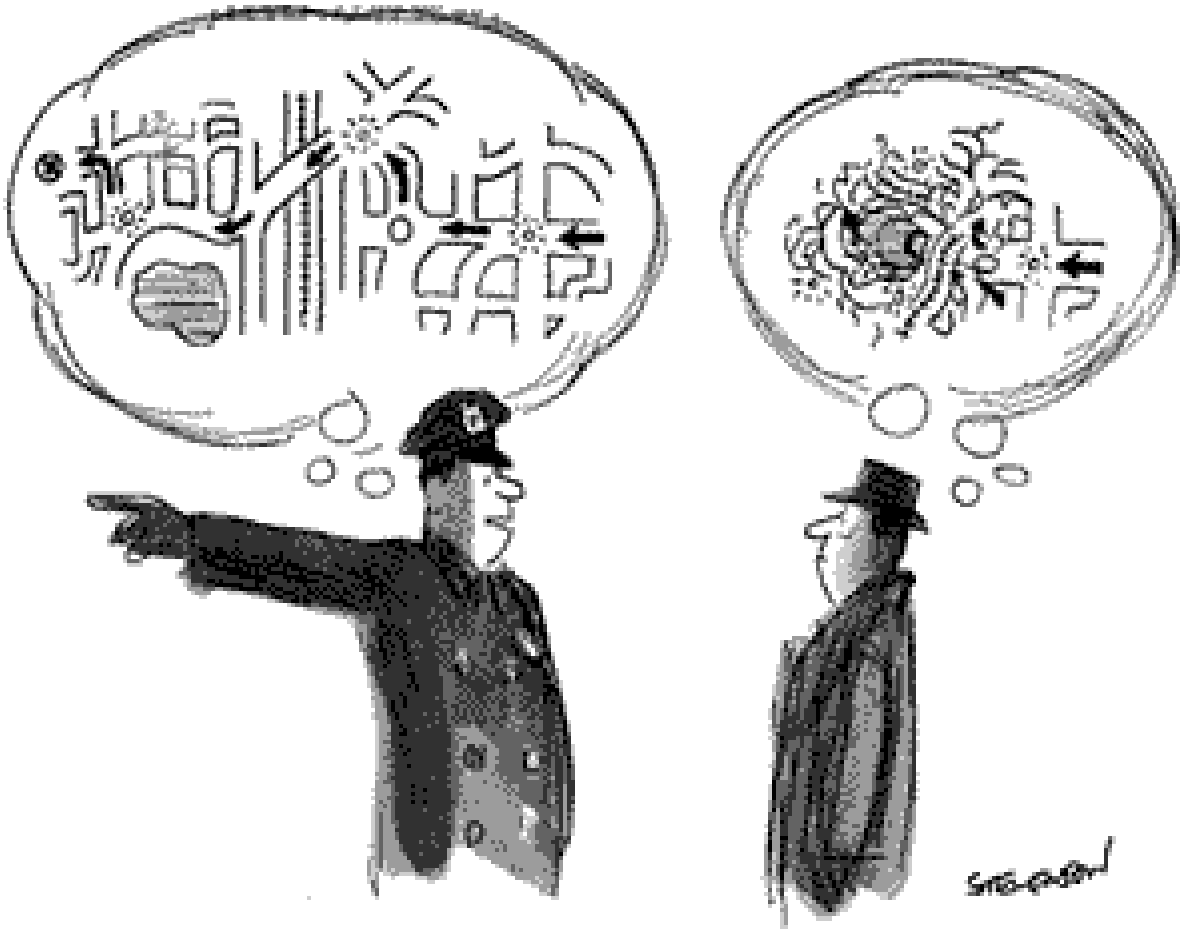
People develop and execute cognitive strategies for visual tasks based on their experience with similar tasks and layouts, the information peripherally available, and human constraints (i.e. foveal vision, eye movements).

My questions:

- What are the cognitive strategies that drive visual search?
- How can we discover them?
- How can we predict them based on task and scene analysis?
- What parts are task-specific?
- What are the invariants?



Cognitive task strategies, like a lot of procedural knowledge, are sometimes more clear, sometimes more fuzzy.



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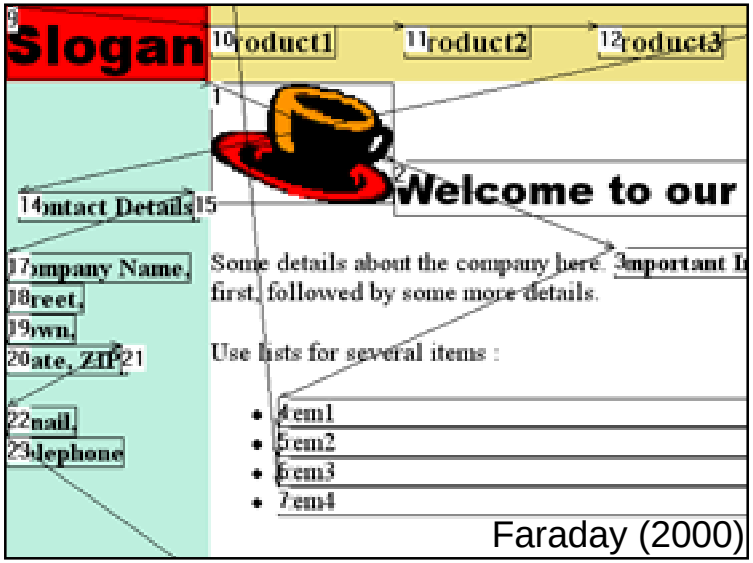
The strategy coordinates the interaction among the visual processes

Combination of:

"Global control" in which knowledge of the scene and task is used to program the eye movements. → Lohse's UCIE--GOMS-based graphical perception--different strategy for each type of layout.

"Local control" in which you move the eyes based on the features in the visual stimuli. → Faraday's ordered taxonomy of visual specifiers: motion, size, images, color, text style, position.

The two work together, i.e. looking for the red PDF icon where you would expect to see it.



Cognitive architectures are useful frameworks for building and testing theories of visual search

EPIC is well-suited for exploring plausible cognitive strategies:

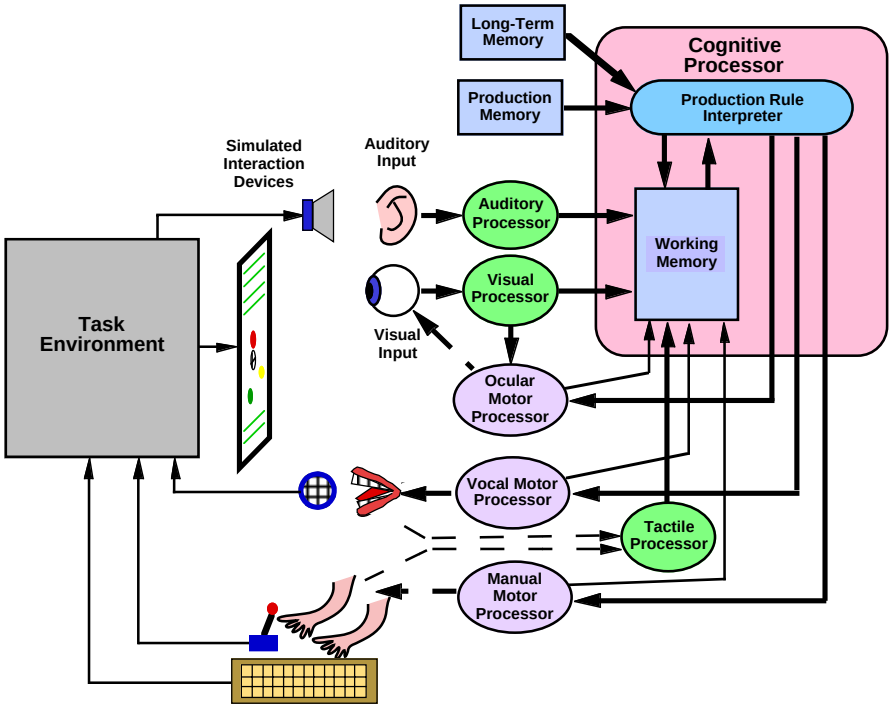
1. Flexible production rule processor--multi-match, multi-fire.
2. Eye movements--no covert visual attention.
3. Foveal region--all detail in fovea is processed in parallel.

My Current Questions:

How much info is picked up with each fixation during a rapid scan?

Sperling's "span of apprehension" of four items? Cowan's magic number four?

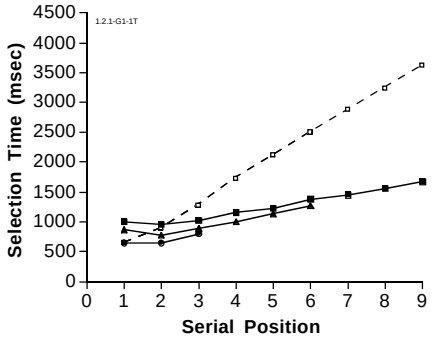
EPIC Cognitive Architecture
Executive Process-Interactive Control



(Kieras and Meyer, 1997)

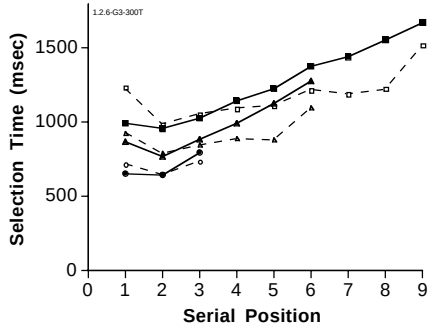
Cognitive modeling of menu search has provided insight into the strategies used for visual search

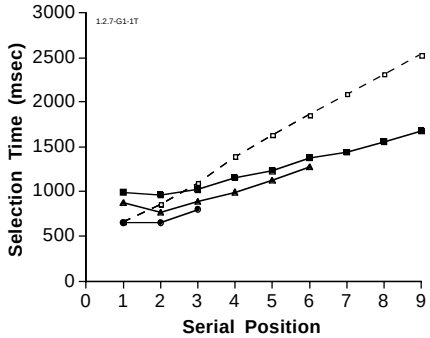
1. More than one item is considered with each fixation.



One item per fixation can't explain.

2. Some combination of random and systematic search.

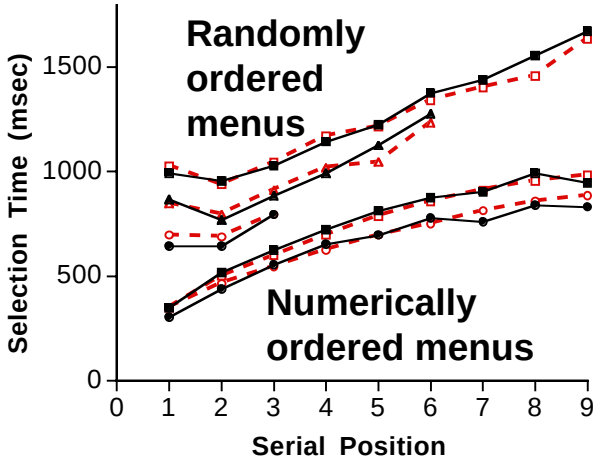




All random or all systematic can't explain.

3. Anticipated locations lead to a very efficient "search."

4. A variety of tasks can be explained by only changing the cognitive task strategy.

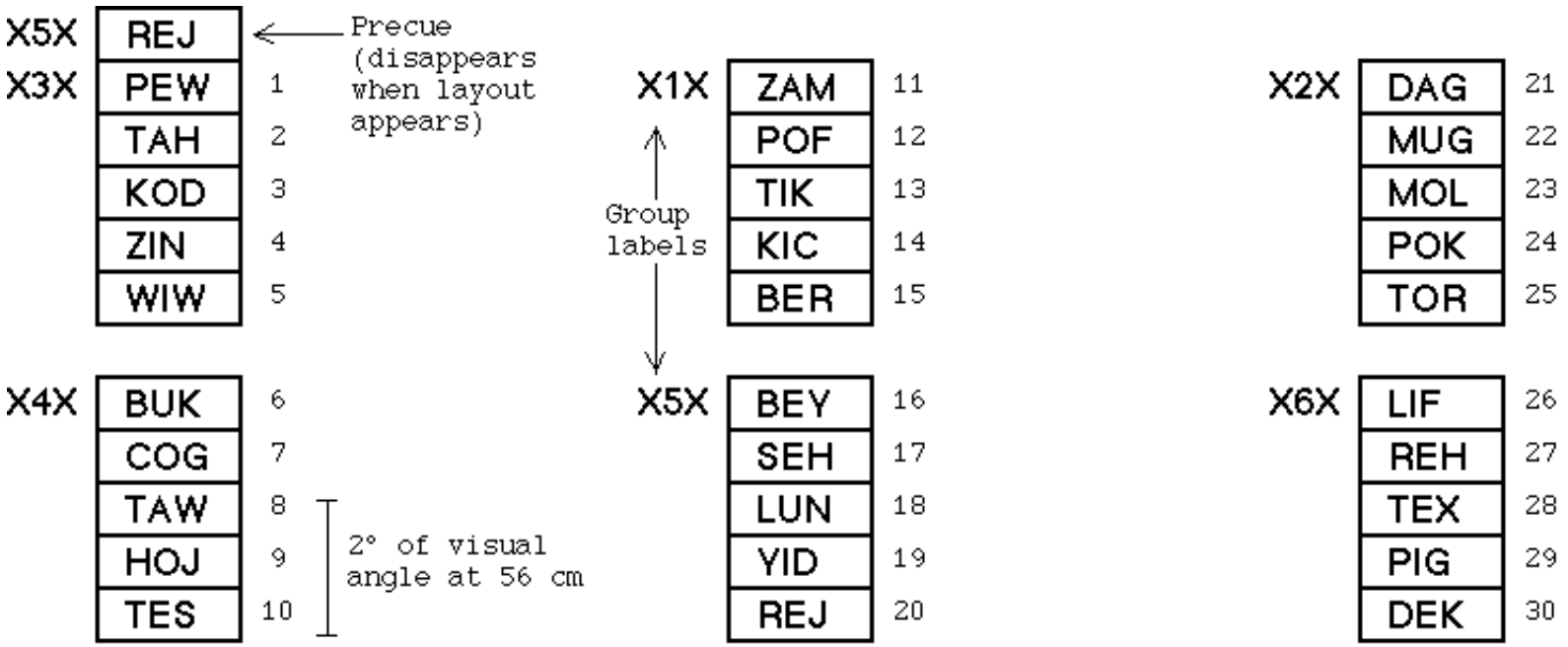


What cognitive strategies do people use to search labeled versus unlabeled hierarchies?

Unlabeled

Labeled

Experiment: Visual search of hierarchical layouts



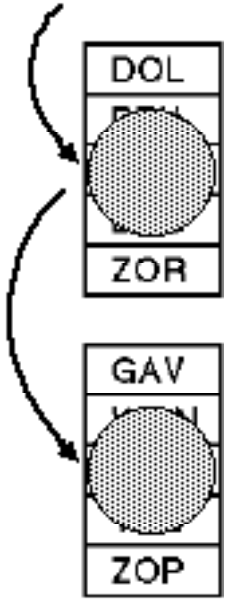
Design

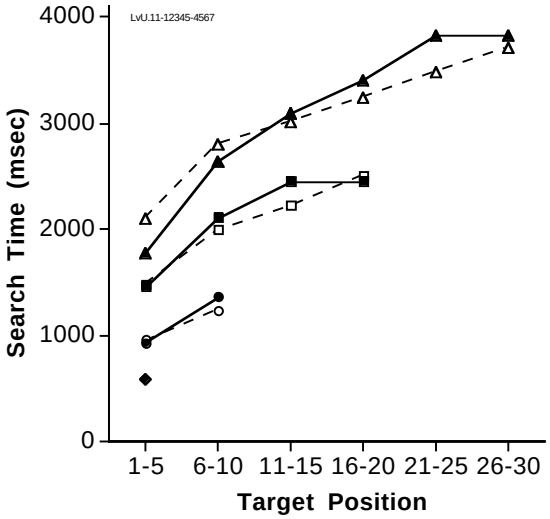
- Procedure: Study precue, click on precue, find target, click on target.
- Layouts have 2, 4, or 6 groups. Some layouts have group labels. Blocked by layout type.
- 16 participants, motivated to search quickly.
- Search and selection time recorded separately.

The models provide insight into the strategies people used to search the hierarchical layouts

Unlabeled

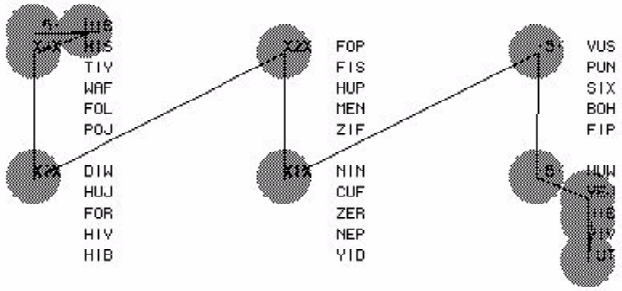
A plausible integration of random and systematic search in a strategy. Perhaps people try to be systematic and thorough, but skip over items.

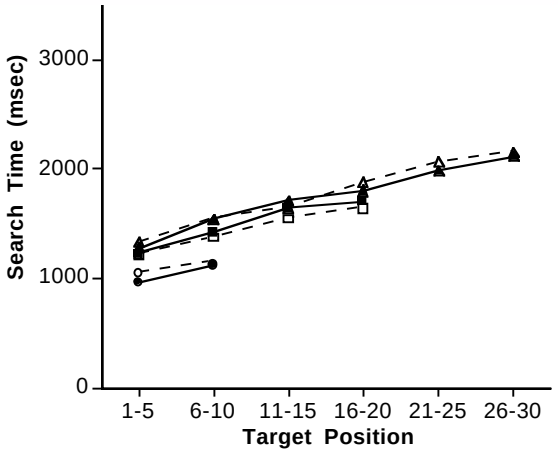




Labeled

Labels are used very efficiently. Highly streamlined strategy.

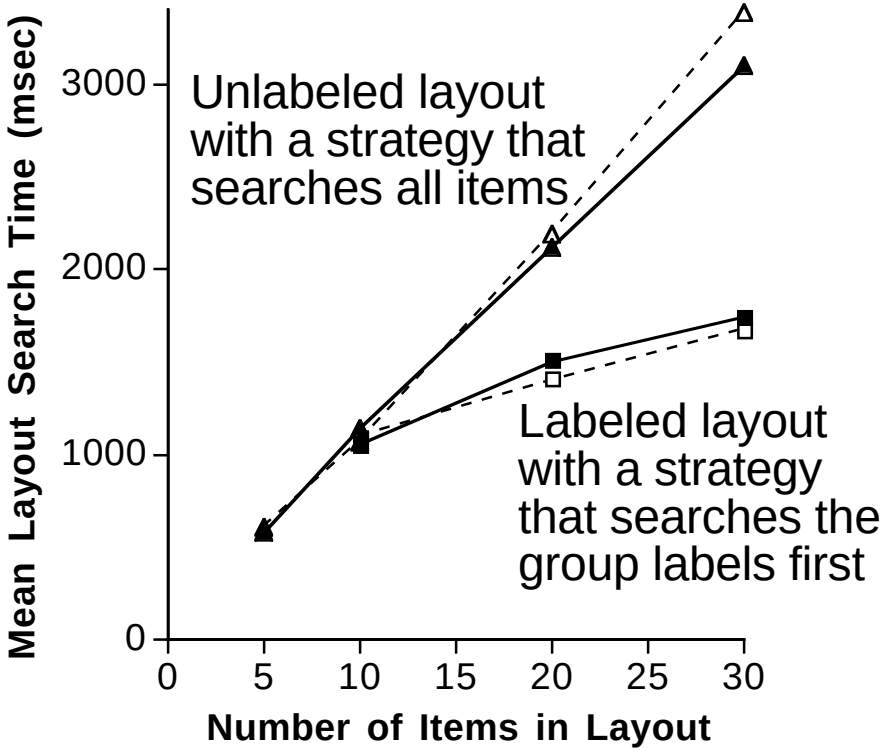


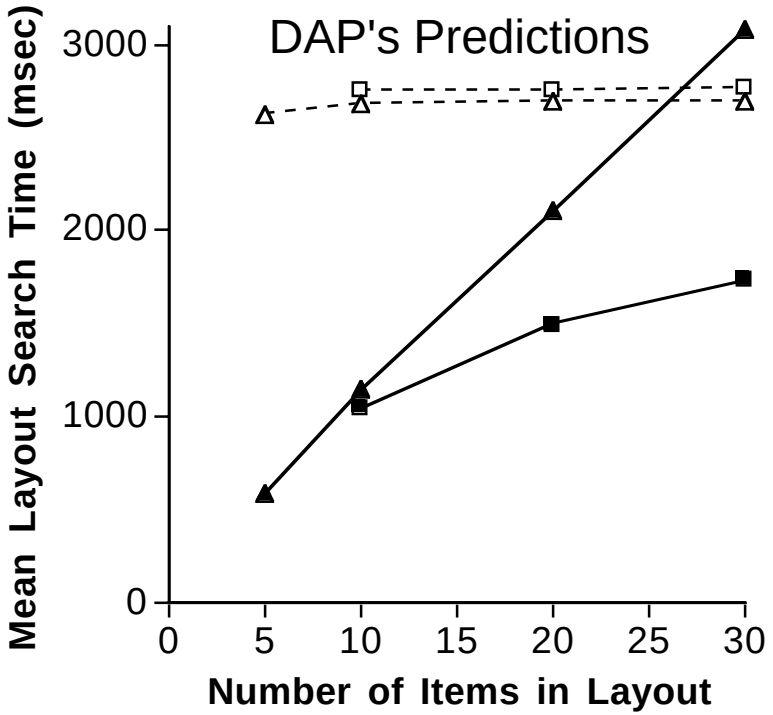


The structure of the layout motivates fundamentally different strategies.

Cognitive strategies are key for predicting visual search

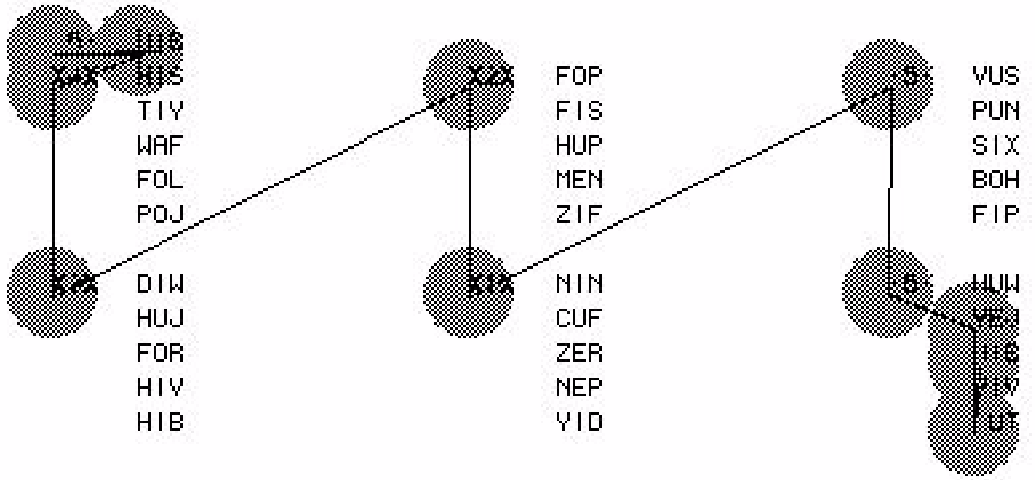
Comparing these models' *post*dictions with the *a priori* predictions of Tullis' Display Analysis Tool (DAP) demonstrates the importance of incorporating cognitive strategies based on the task and the structure of the layout.



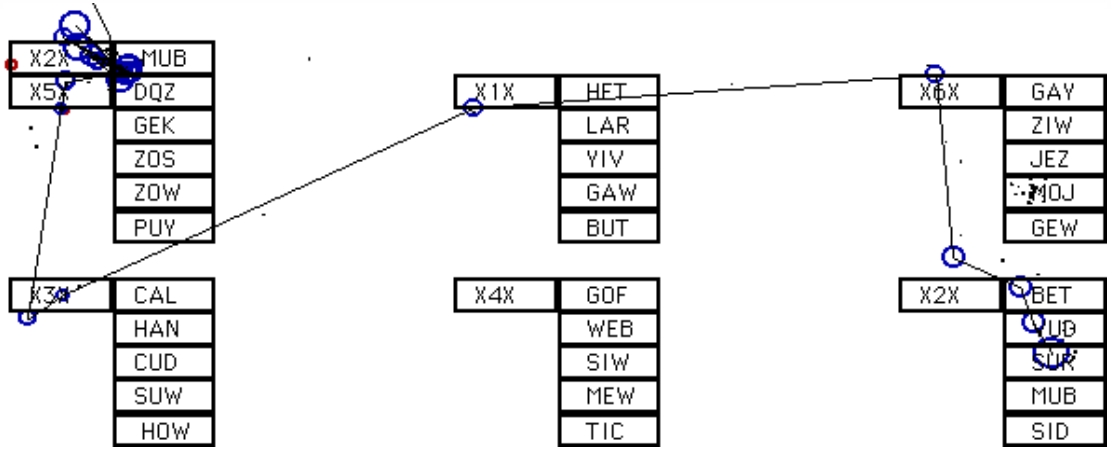


How can eye tracking data help?

EPIC running the label-following search strategy. Is the model correct?



One trial of eye movement data from a labeled layout. What is this person doing?



Two complementary questions

How can eye tracking data help?

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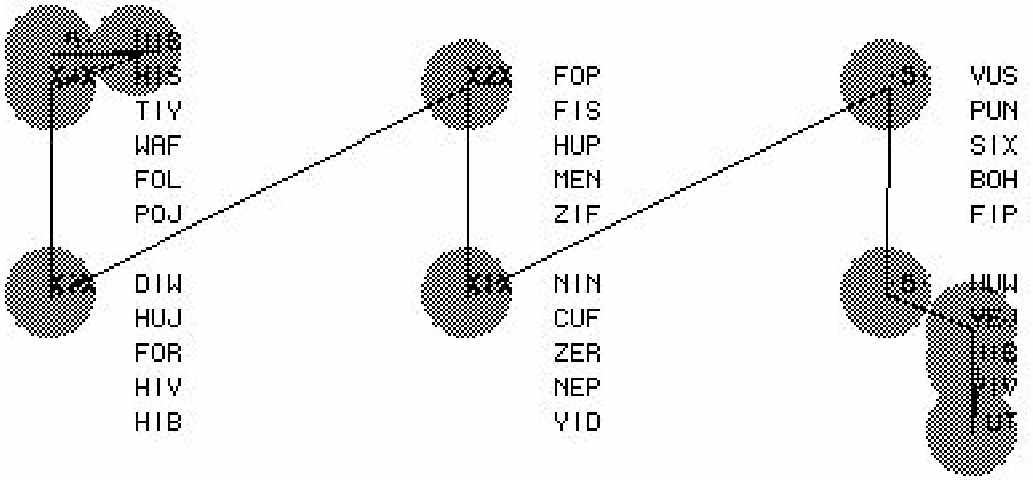

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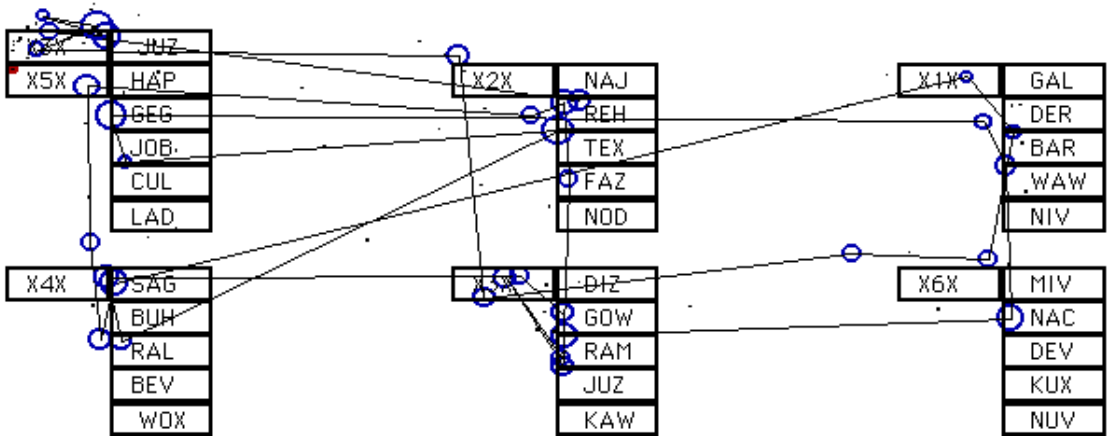
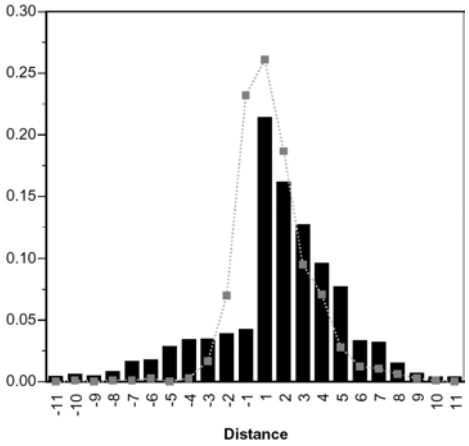


Two complementary questions

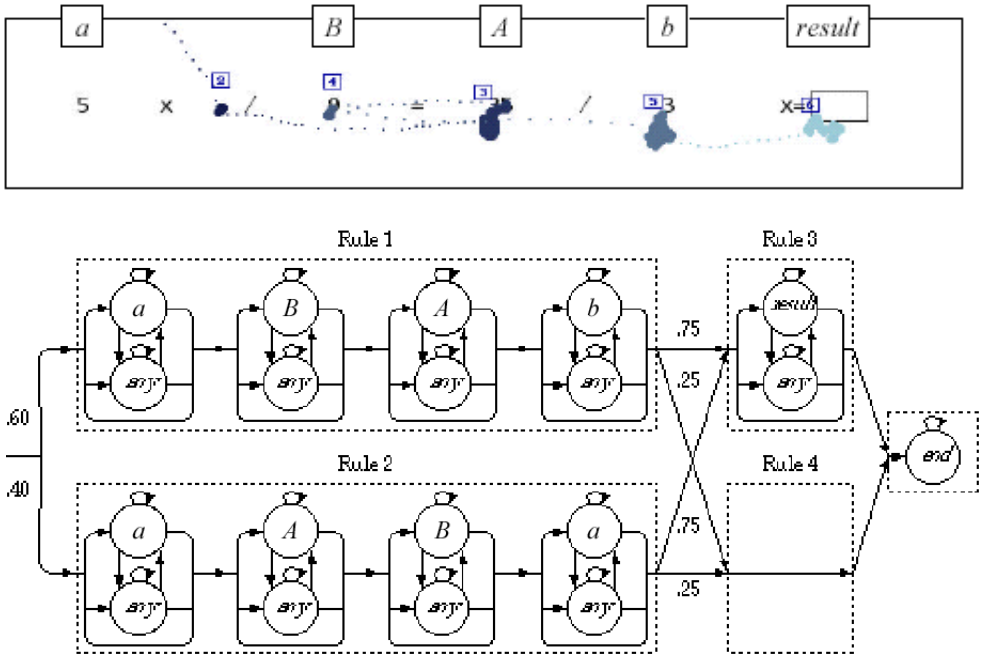
Not easy to answer

Eye movement data can help to reveal the cognitive strategies

Summary statistics: Histogram of saccade distances (Byrne, 2001)

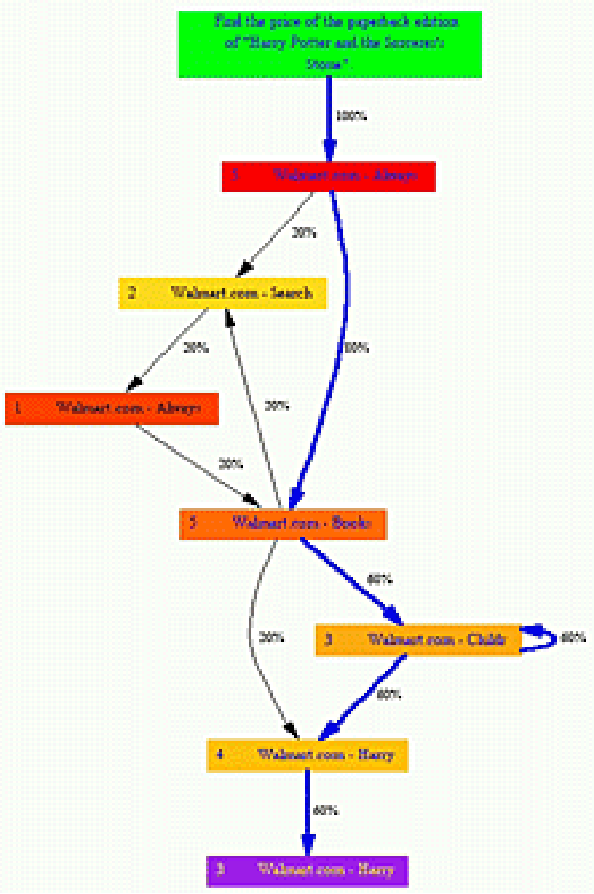


Strategy classification using HMMs (Salvucci and Anderson, 2001)

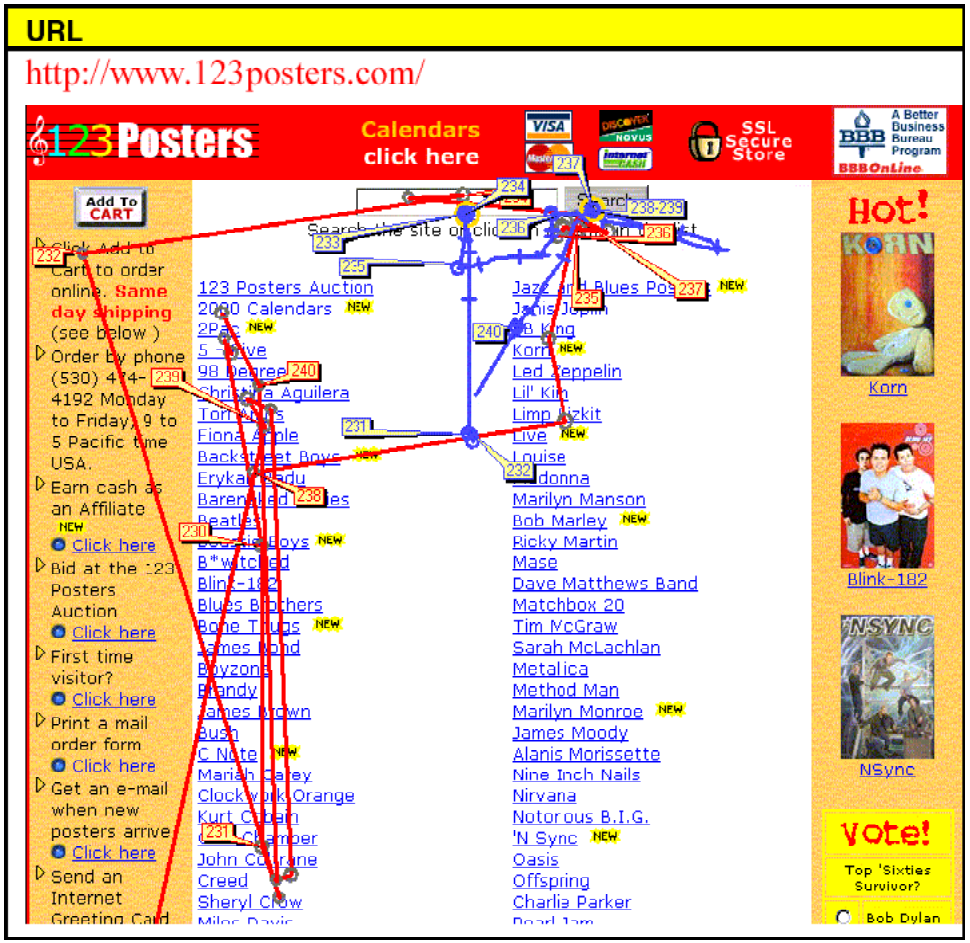


How can we automatically classify patterns of eye movements when the question is one level abstracted from specific locations?
For example: Did the participants follow the labels in any order?

Perhaps some general-purpose tools can be developed to detect a wide range of behavior

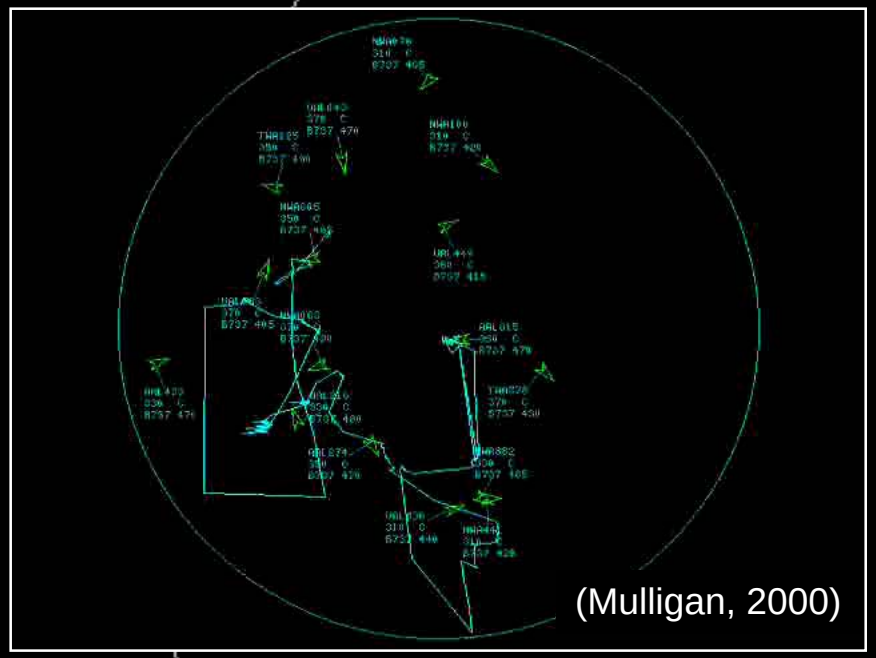


NetRaker.com
Clickstream
Visualization



PARC's WebEyeMapper
(Card et al., 2001)

Perhaps cognitive strategies for ATC tasks can be identified using eye tracking data



(Mulligan, 2000)

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NWA825
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B737 405

TWA608
350 C
B737 410

AAL091
330 C
B737 405

UAL784
370 C
B737 465

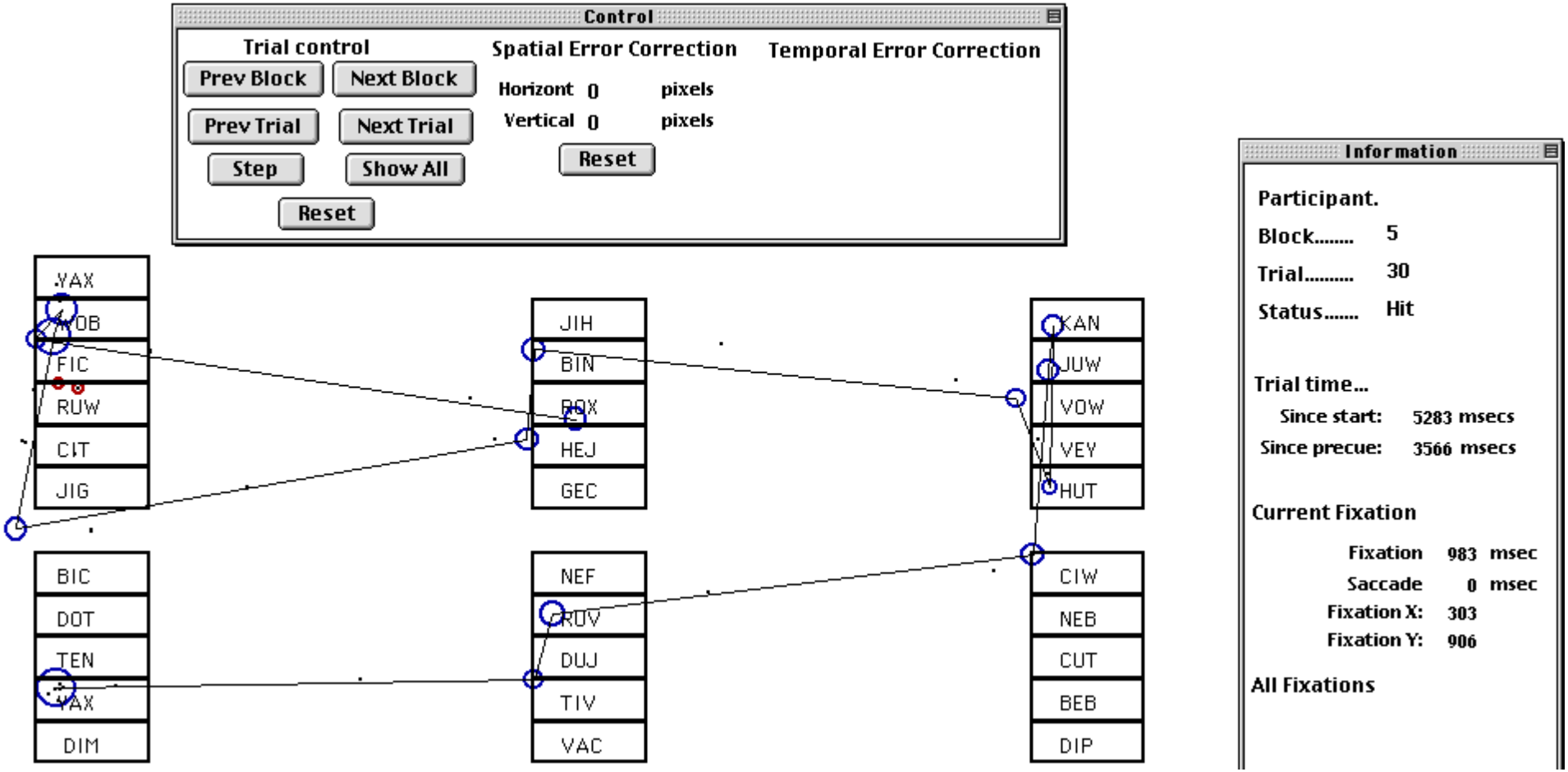
UAL285
350 C
B737 445

NWA114
310 C
B737 475

AAL184
370 C
B737 425

http://vision.arc.nasa.gov/personnel/jbm/home/projects/arvo00/poster_frame.html

Developing VizFix--a tool for visualizing and detecting eye movement patterns



What experiment to run next?

An open-ended web task? A focused web task? Perhaps give a text-comprehension test afterwards, and correlate performance with automatically-identified reading behavior.

Search tasks to establish lobe characteristics for different stimuli during a series of rapid fixations.

What experiment are you all running? How might your data be useful for identifying cognitive strategies?

Conclusion -- My general questions

1. What are the cognitive strategies that drive the visual search processes?
2. How does the visual task and visual layout affect the strategy selection and execution?
3. How can exploratory cognitive modeling help to identify these strategies?
4. How can eye tracking help to identify these strategies?
5. How do cognitive modeling and eye tracking complement each other to answer these questions?

The long term contributions: Predictive modeling, better theories of interface design and human performance