Investigating the incidental learning of location information in a visual search task

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Learning in diagrammatic reasoning

- In diagrammatic reasoning, what does the user learn about the diagram in the course of using it?
- Using Cartesian graphs, certain graphical elements are fixed (e.g. axis labels, tick labels). When do users stop searching for graphical elements and start remembering where they are?
- When modelling diagrammatic reasoning tasks, assumptions have to be made about the search for information and the learning of the locations of this information.
- This is complicated by the fact that experienced users of graphs have general graph knowledge about the typical locations of certain information (e.g. scales increase from left to right and bottom to top).

Previous fixes

- Hard code x and y location of individual labels.
- Hard code one dimension, leave other free (e.g. x axis tick labels “below x axis”).
- Hard code range of locations to limit search (e.g. x axis range 0 to 9, tick labels 7, 8, 9 “below x axis and to the right”).
- Axis, tick and plot point label learning.(e.g. “try to remember location of x axis label 7, if retrieval successful look there, if not, search within restricted range”)
- Problem as learning and retrieval mechanisms every time a label is used make diagrammatic reasoning models very large, complex and increasingly difficult to understand.

Other work on location learning

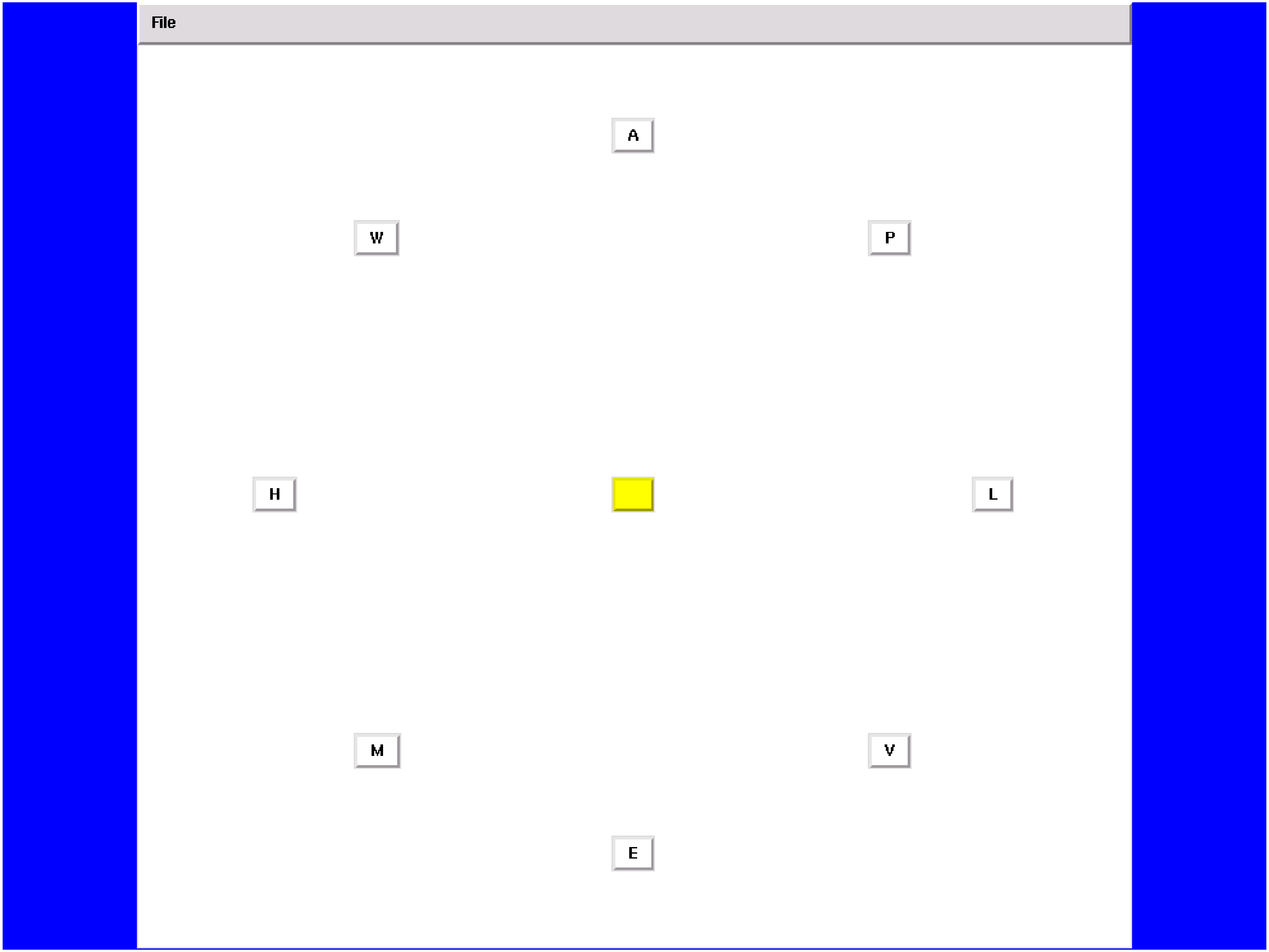
- Brian Ehret's PhD thesis with Wayne Gray. Investigated location learning in context of search and evaluation cost for different types of button labels (e.g. text, colour, icon, etc.).
- Showed that people behaved rationally by learning locational information to the extent that this was required by the label (i.e. minimised the cost of interaction).
- Ehret produced ACT-R/PM (4.0) model which accounted for learning and eye movement data from experiment.
- Manipulated presentation frequency in one experiment. Two levels (high and low). Found frequency interacted with effects of label type.

This study

- Simple experiment to examine the rate of location learning with exposure.
- More detailed and sytematic study of the effect of presentation frequency on location learning.
- Investigate the effect of different modes of presentation on location learning; differences between "short burst" versus "long exposure" presentation.
- Can ACT-R model account for both presentation styles with single set of parameters.

Experiment

- 36 participants asked to do visual search task requiring identification of target letter in circle of 8 buttons displaying distractor letters.
- 8 targets (G, K, O, Y S, T, V, X), 8 distractors (A, H, P, E, L, Z, W, M)
- Locate each letter 64 times = 512 trials divided into 8 blocks of 64 trials.
- 1 within subjects variable; **presentation frequency** (2 letters = 1 loc, 2 letters = 2 locs, 2 letters = 4 locs, 2 letters = all 8 locs).
- 1 between subjects variable; **presentation format** ("sequential" = each target letter presented 8 times in a row, "distributed" = each target letter presented once in every 8 trials). In both conditions each target letter is presented 8 times per block.


File
A
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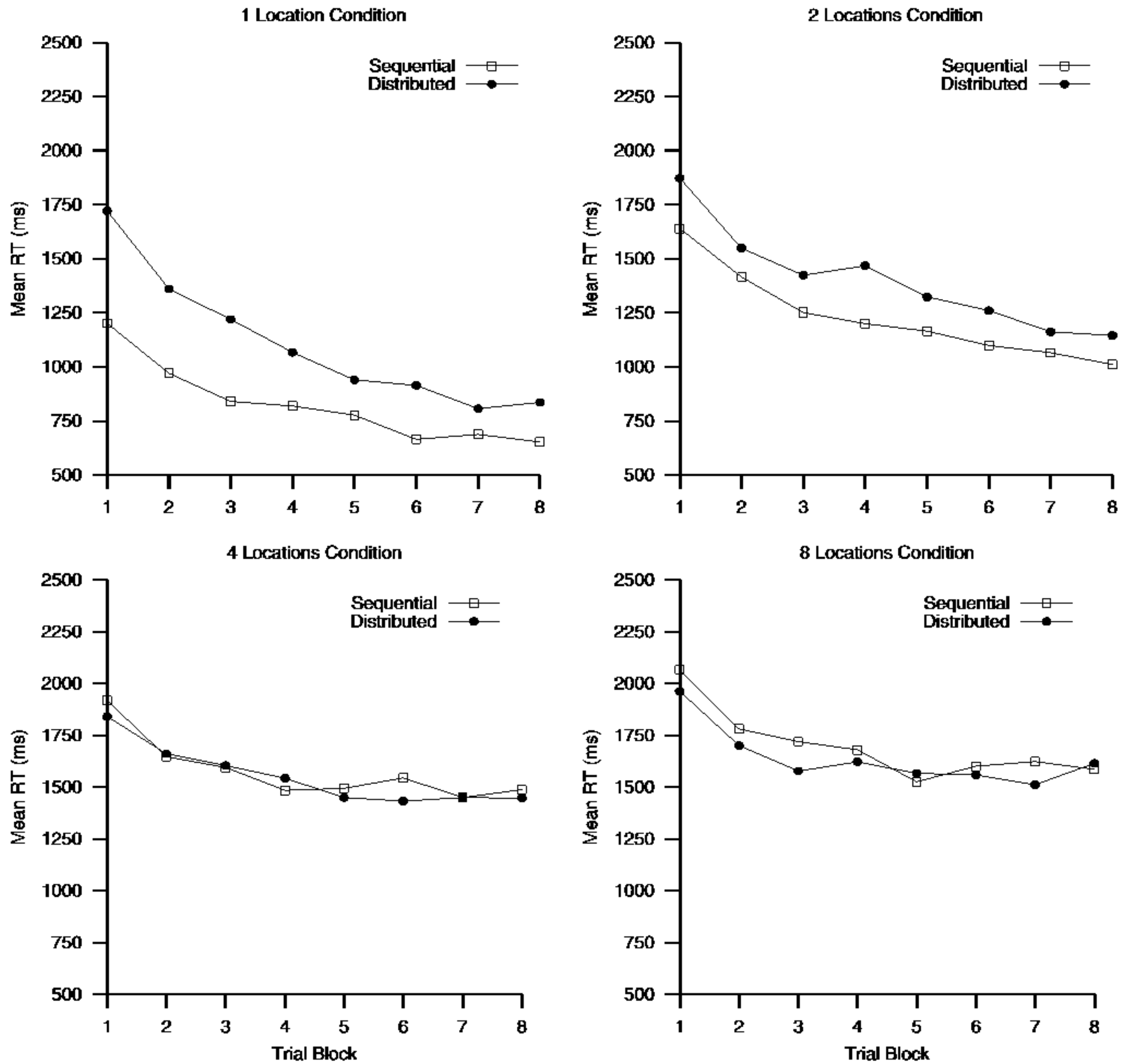
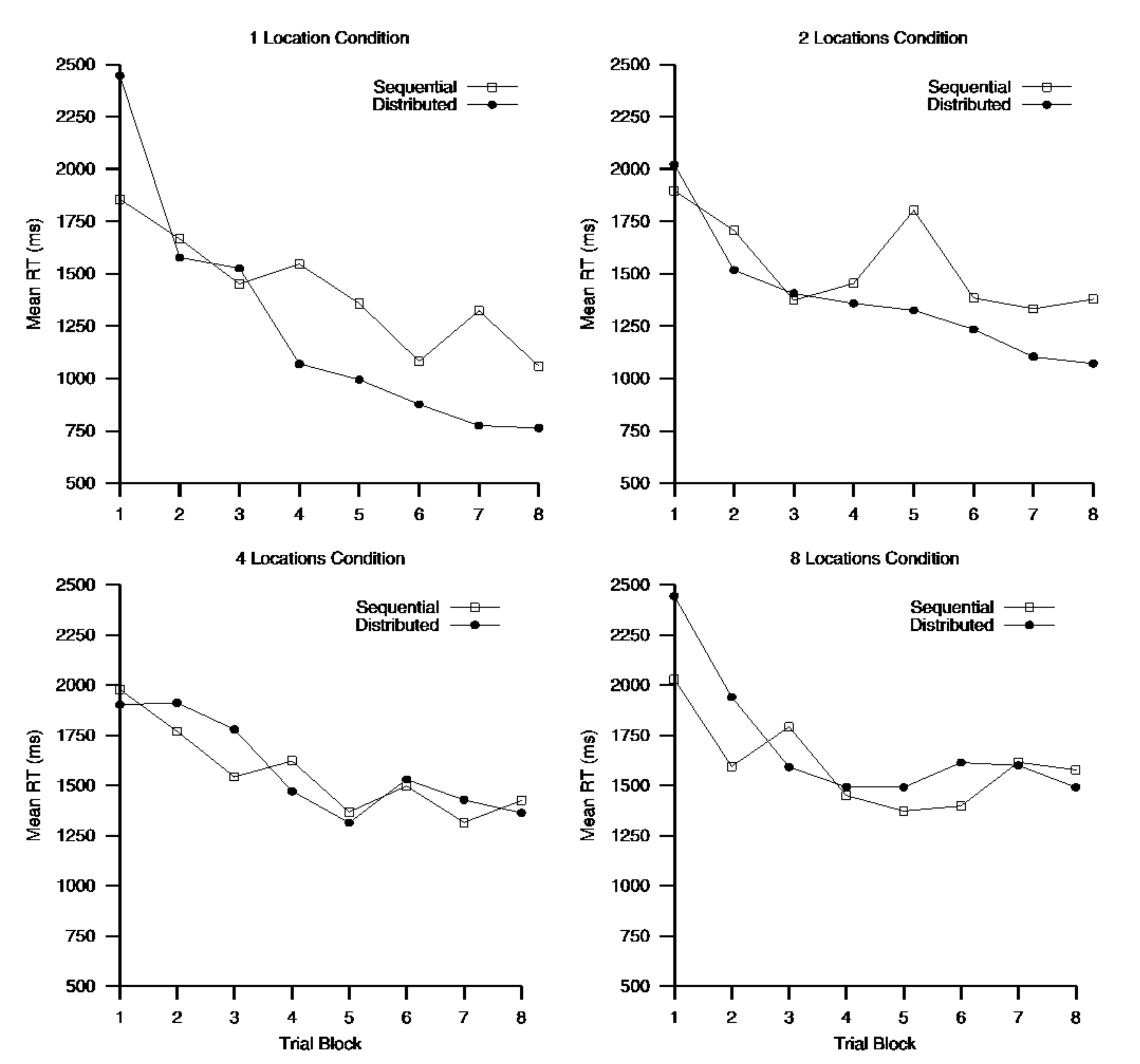


Observed search times averaged over all presentations in a block



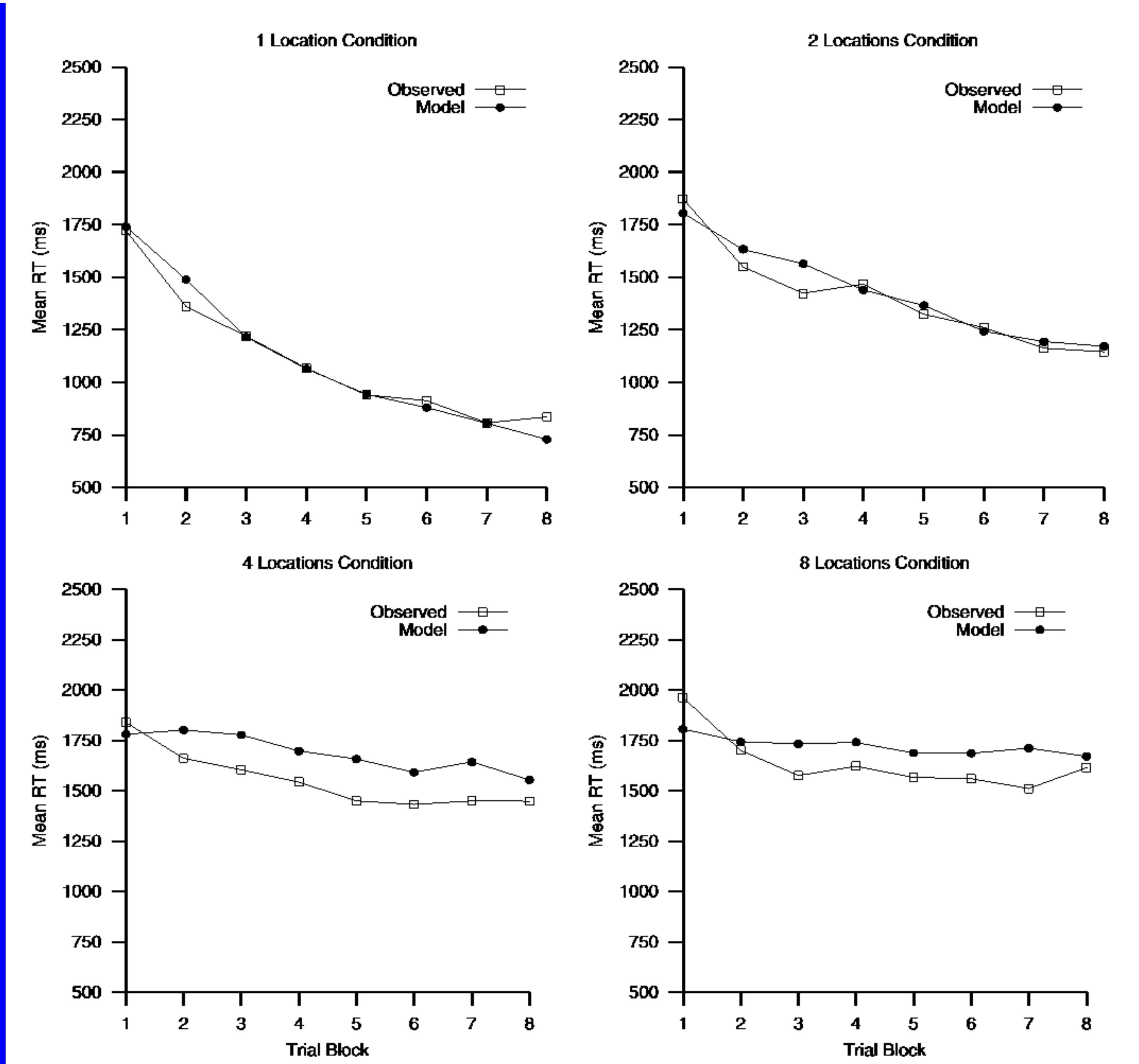
Observed search times averaged over first presentation in a block

ACT-R model

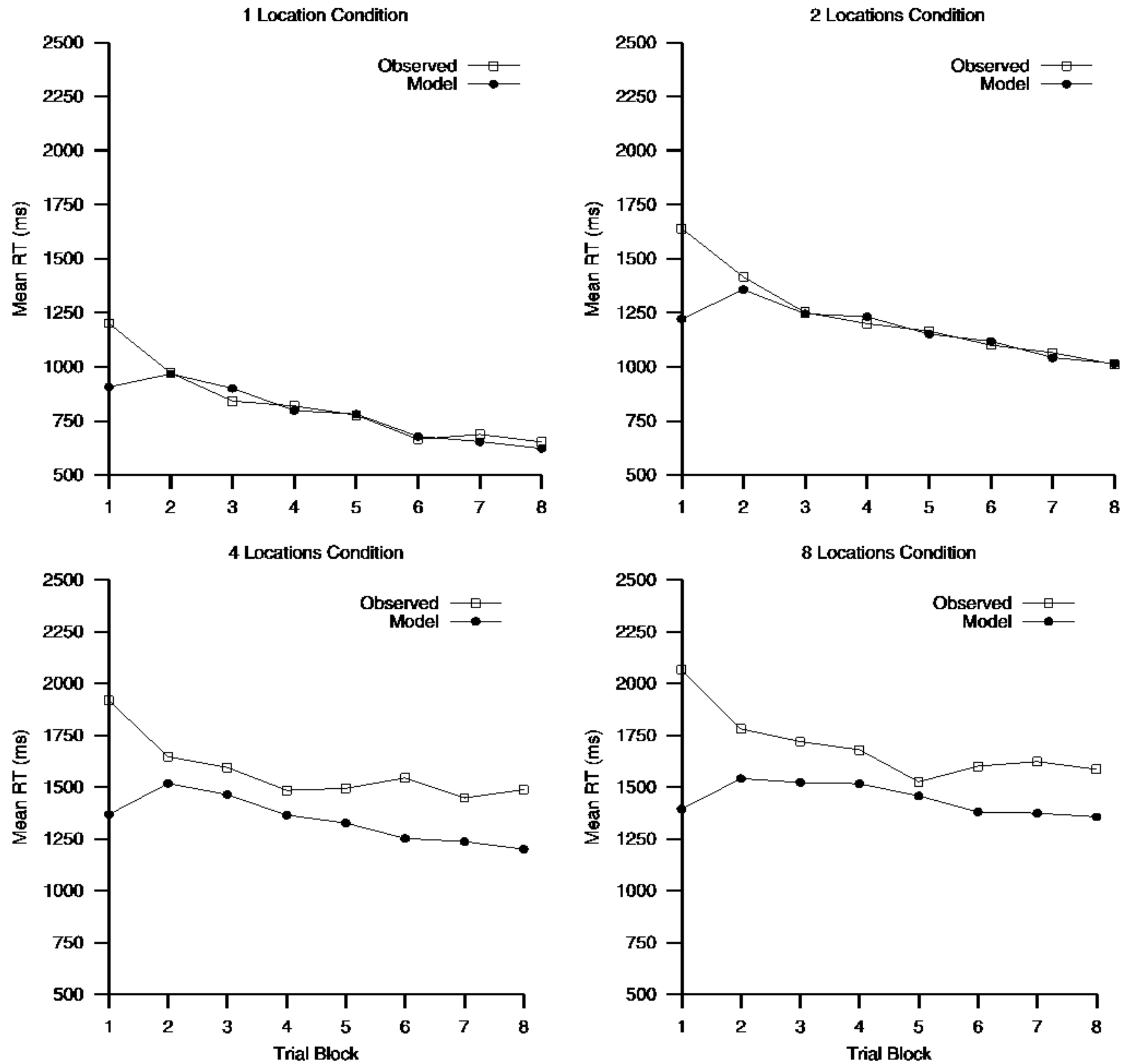
- Implemented in ACT-R 5.0 and run on subject trial files
- GOAL CHUNK (identify-target-letter state target-letter screen-pos)
- Look for target letter at circle centre & click centre button.
- Try to remember previous experience (goal chunk) of locating target letter at specific location on circle.
- If retrieval **successful**, look at remembered location on circle.
- If retrieval **unsuccessful**, look at random location on circle.
- If currently attended location on circle **doesn’t** contain target letter, look to an adjacent unattended location.
- If currently attended location on circle **does** contain target letter, click mouse on centre button, etc.
- After each successful trial, goal chunk is created or strengthened.

Model parameters

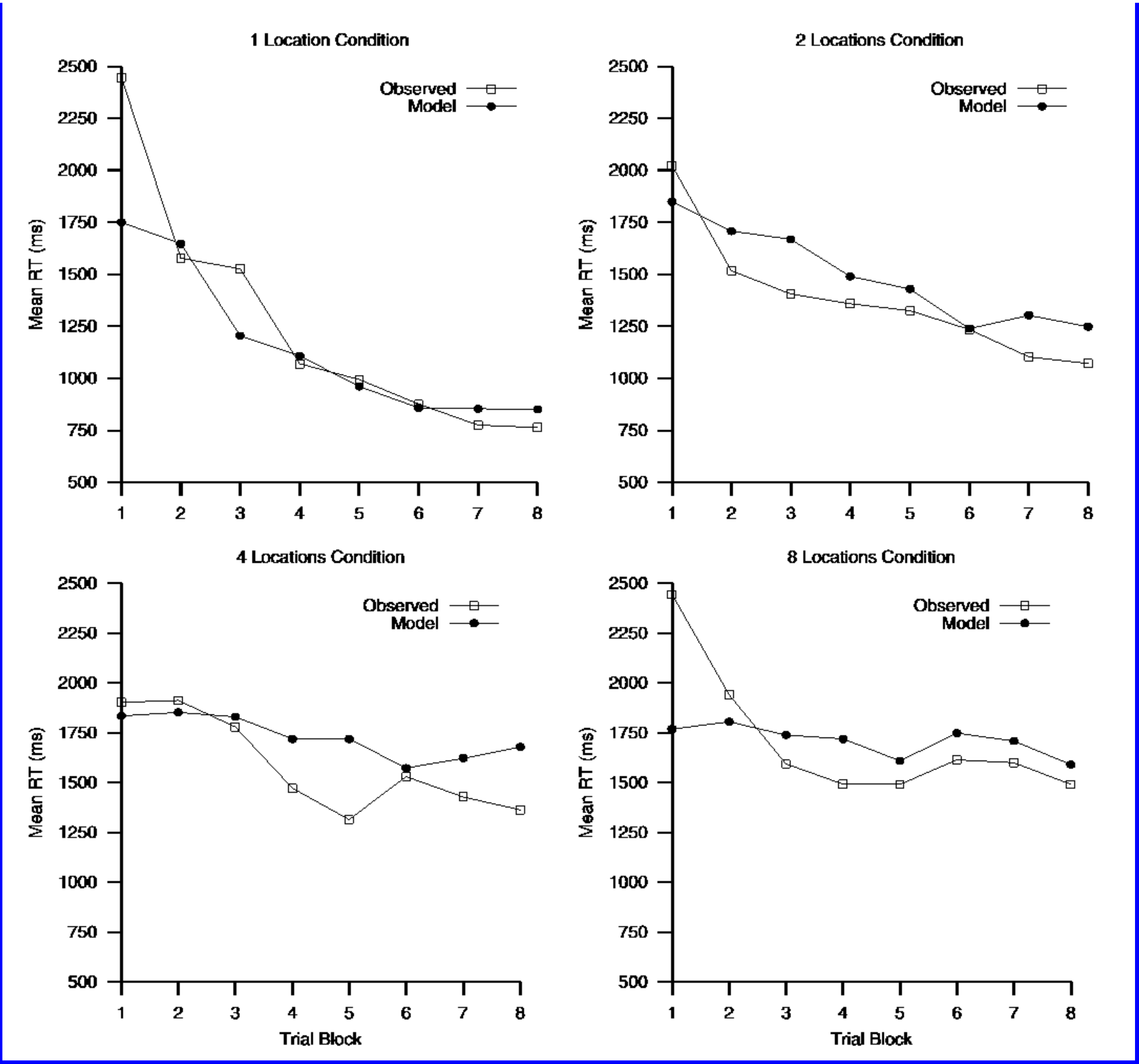
- Set for the distributed condition and not changed for the sequential condition.
- Activation noise = 0.2
- Permanent activation noise = 0.2
- Expected gain noise = 0.01 (0.0)
- Latency factor = 1.2 (1.0)
- Base level learning = 0.62 (0.5)
- Parameters learning = T



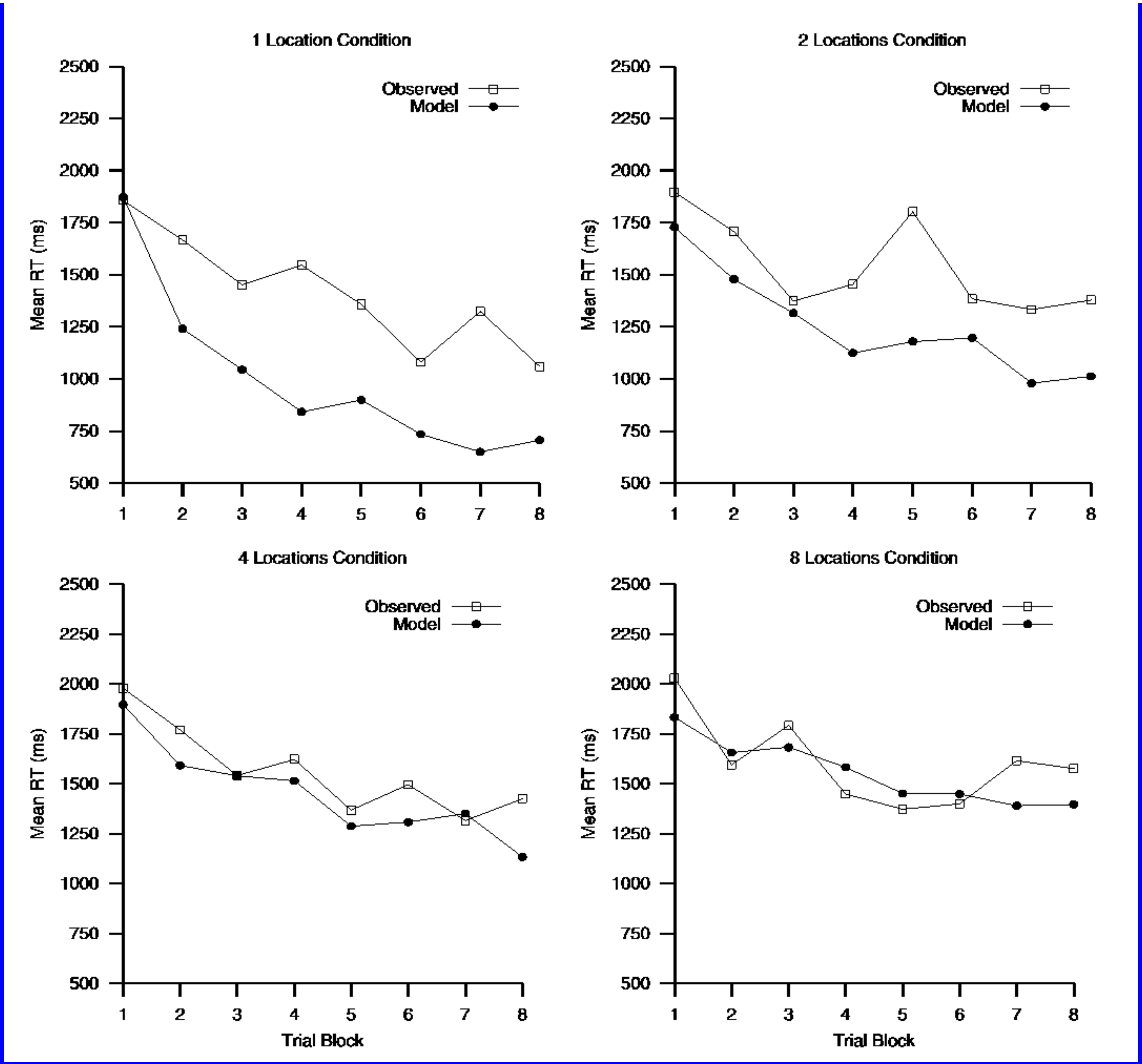
Mean observed and model search times, distributed condition ($R^2 = 0.85$)



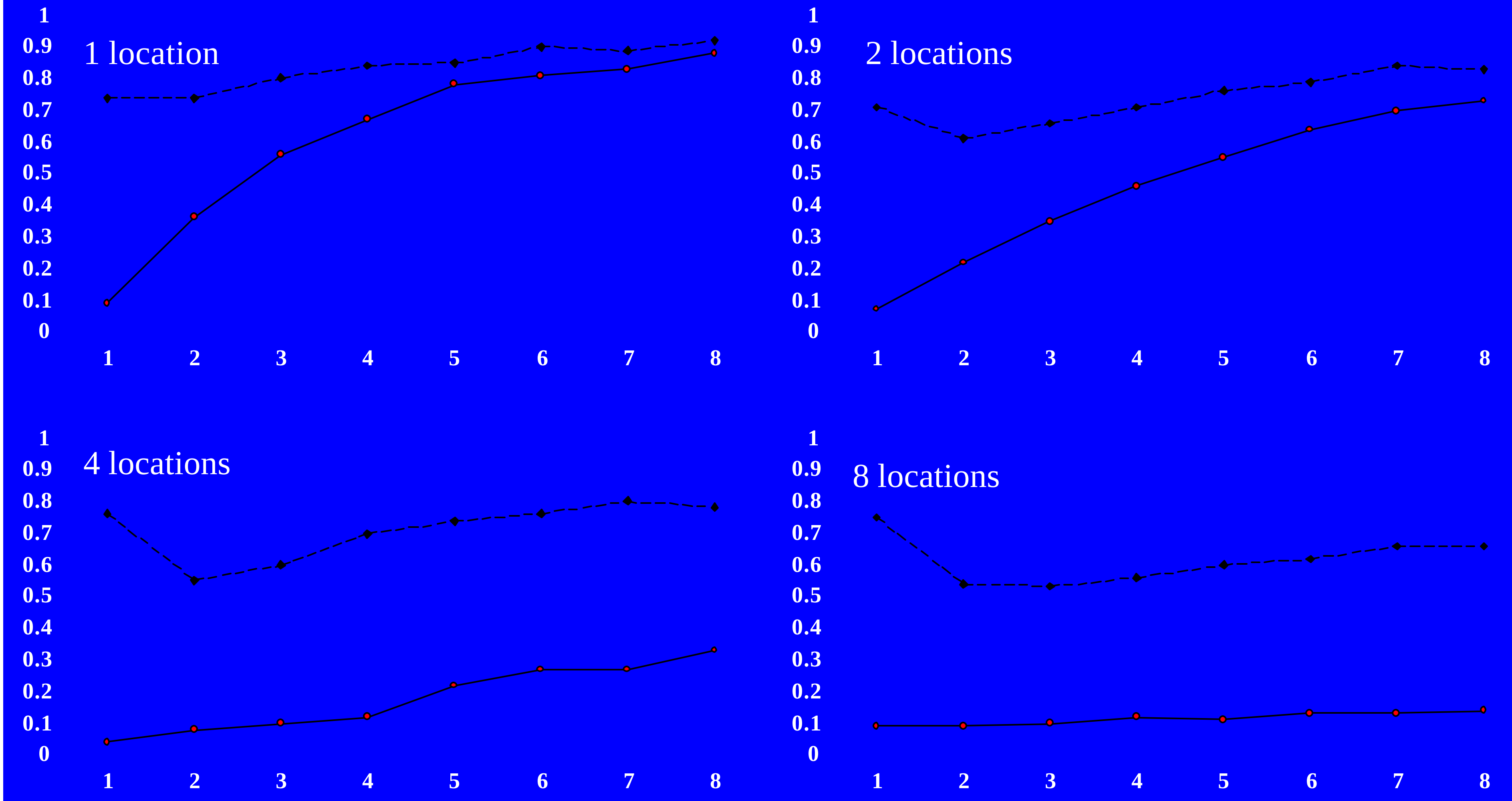
Mean observed and model search times, sequential condition ($R^2 = 0.65$)



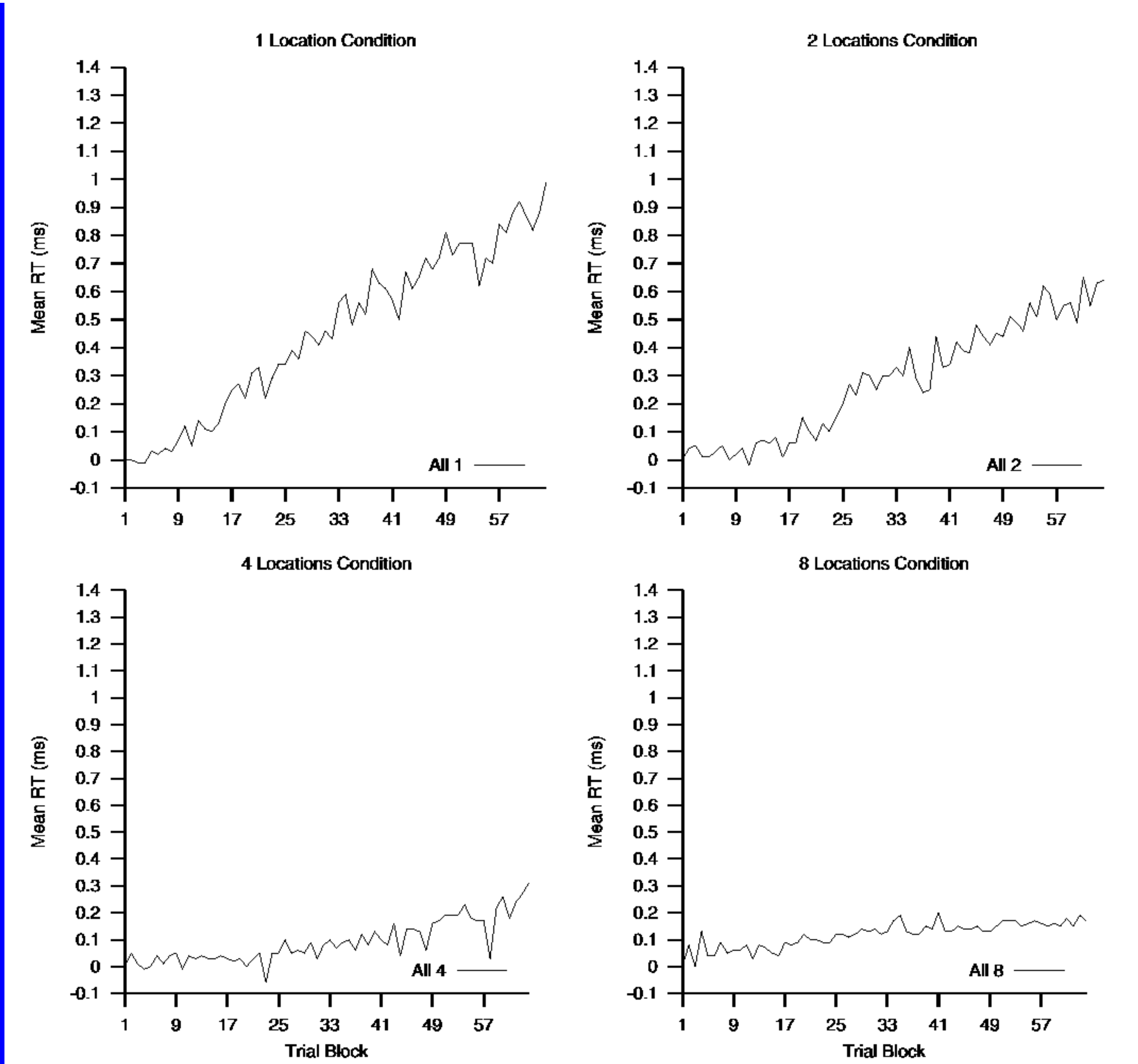
Mean observed and model search times, first block presentation, distributed condition ($R^2 = 0.65$)



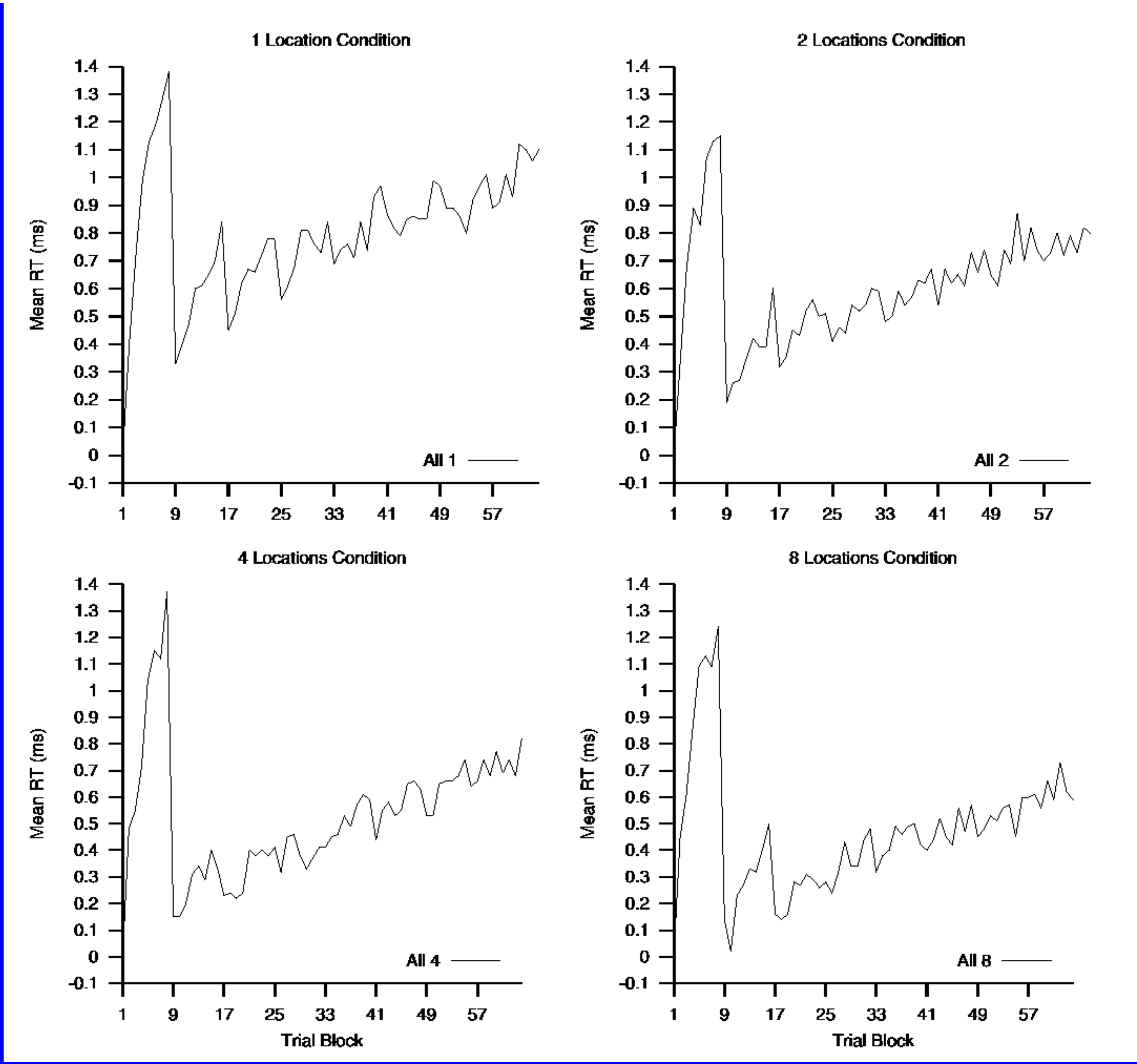
Mean observed and model search times, first block presentation, sequential condition (R^2 = -0.74)



Proportion of goal chunk retrievals, sequential (black square) and distributed (red circle) conditions



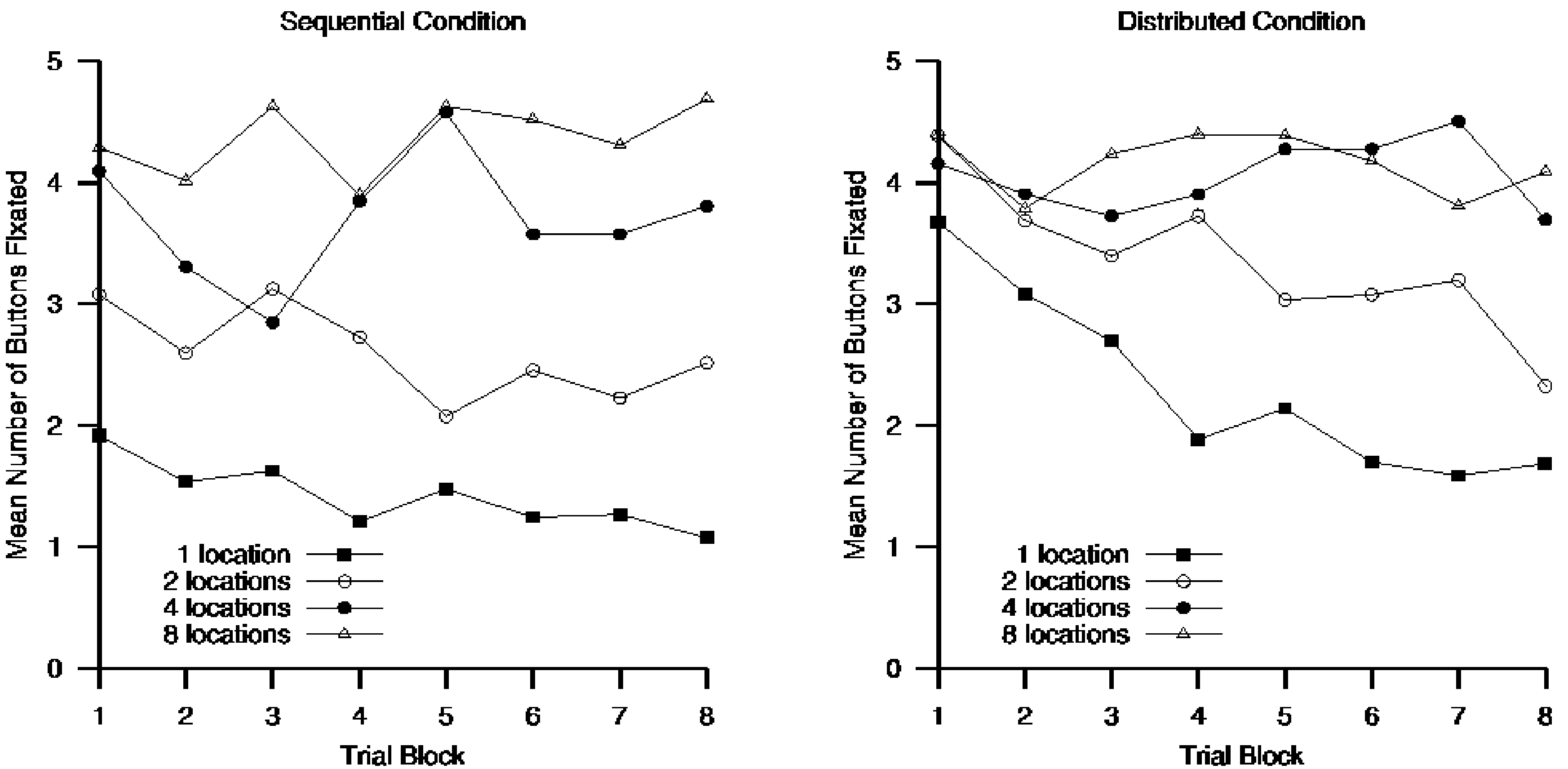
Mean activation of retrieved chunks, distributed condition



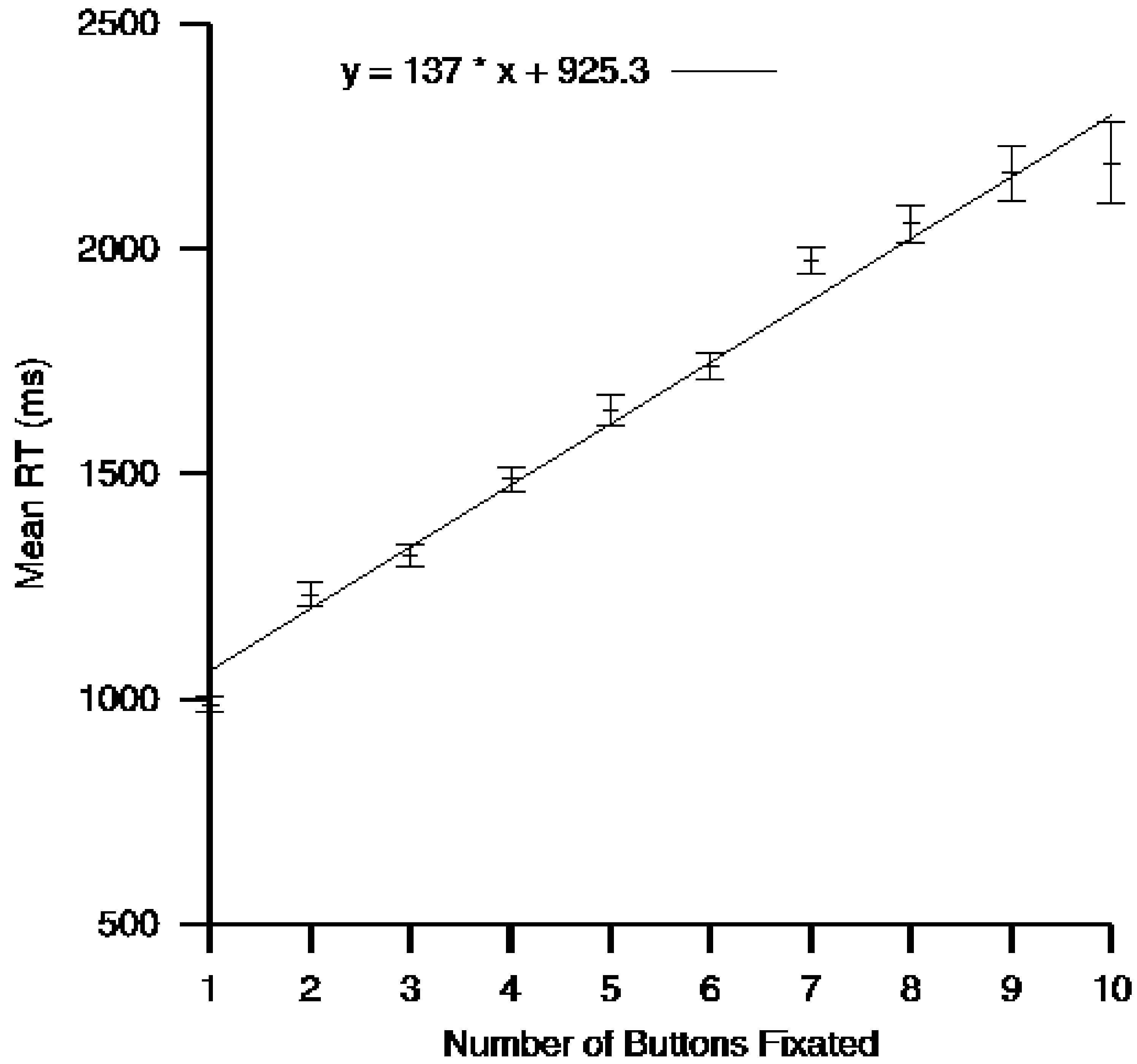
Mean activation of retrieved chunks, sequential condition

Eye movement study

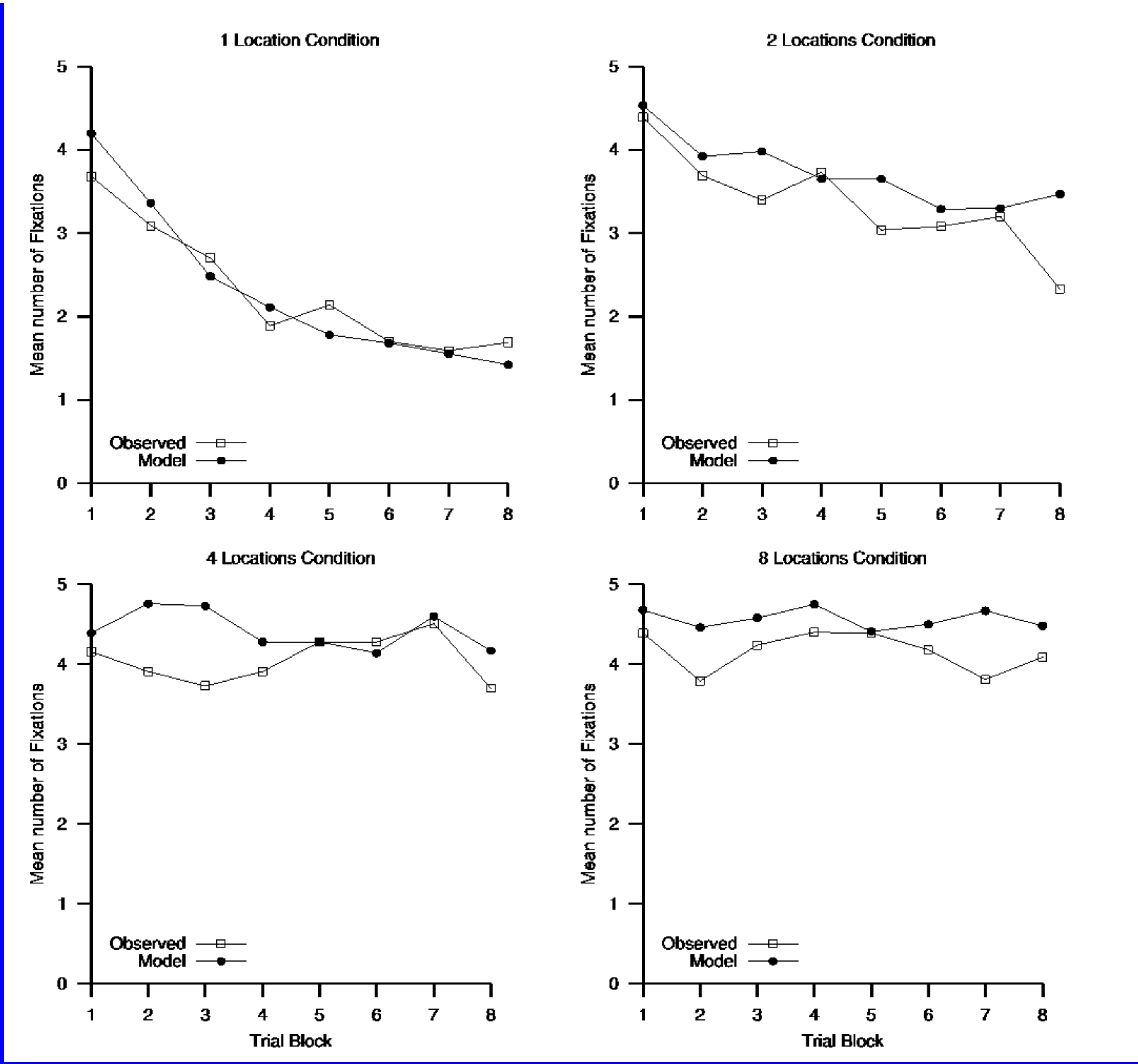
- Eye movements recorded from 4 participants in each condition.
- Eye data from each trial analysed into saccades and fixations over buttons.



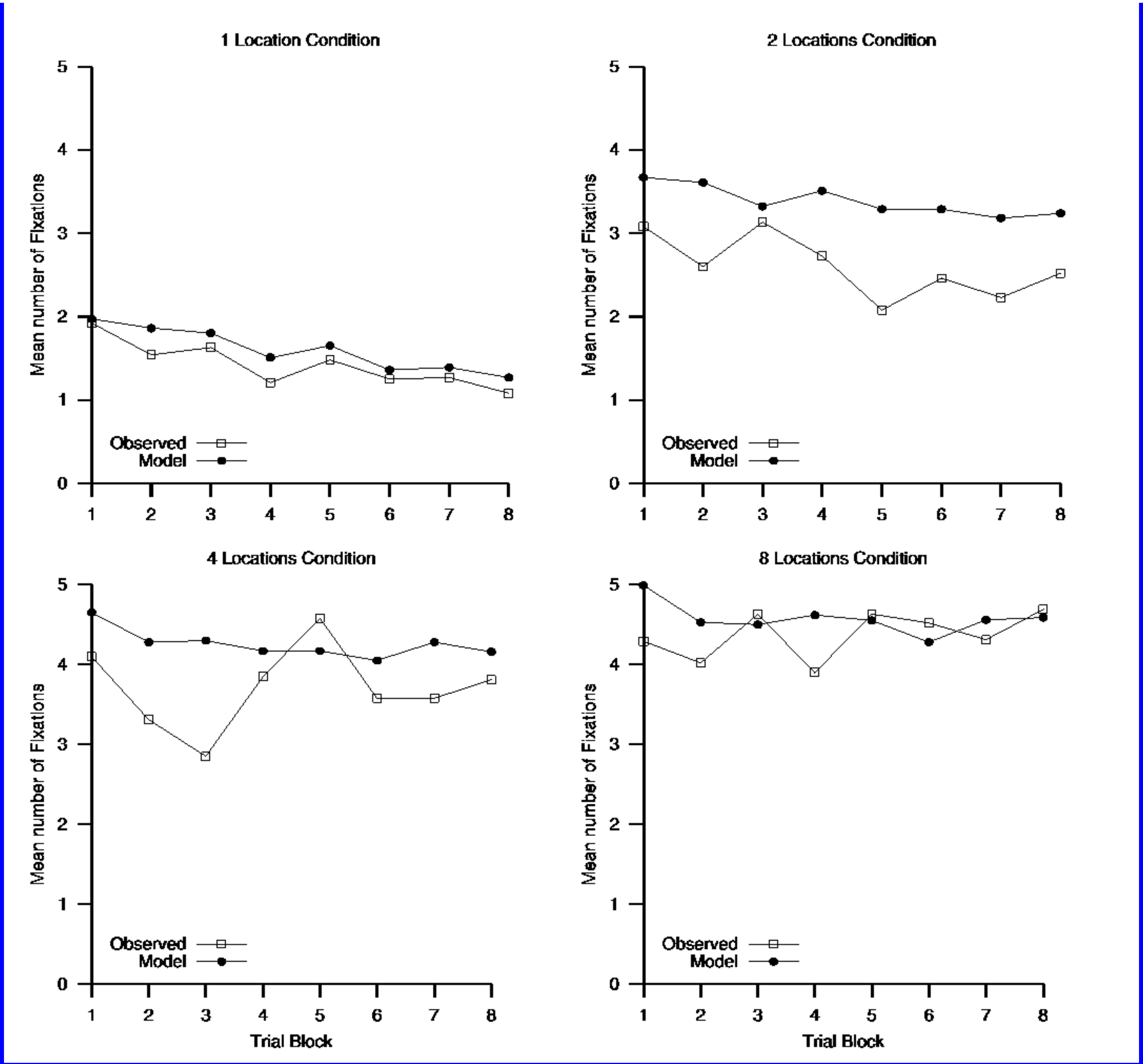
Mean number of buttons fixated



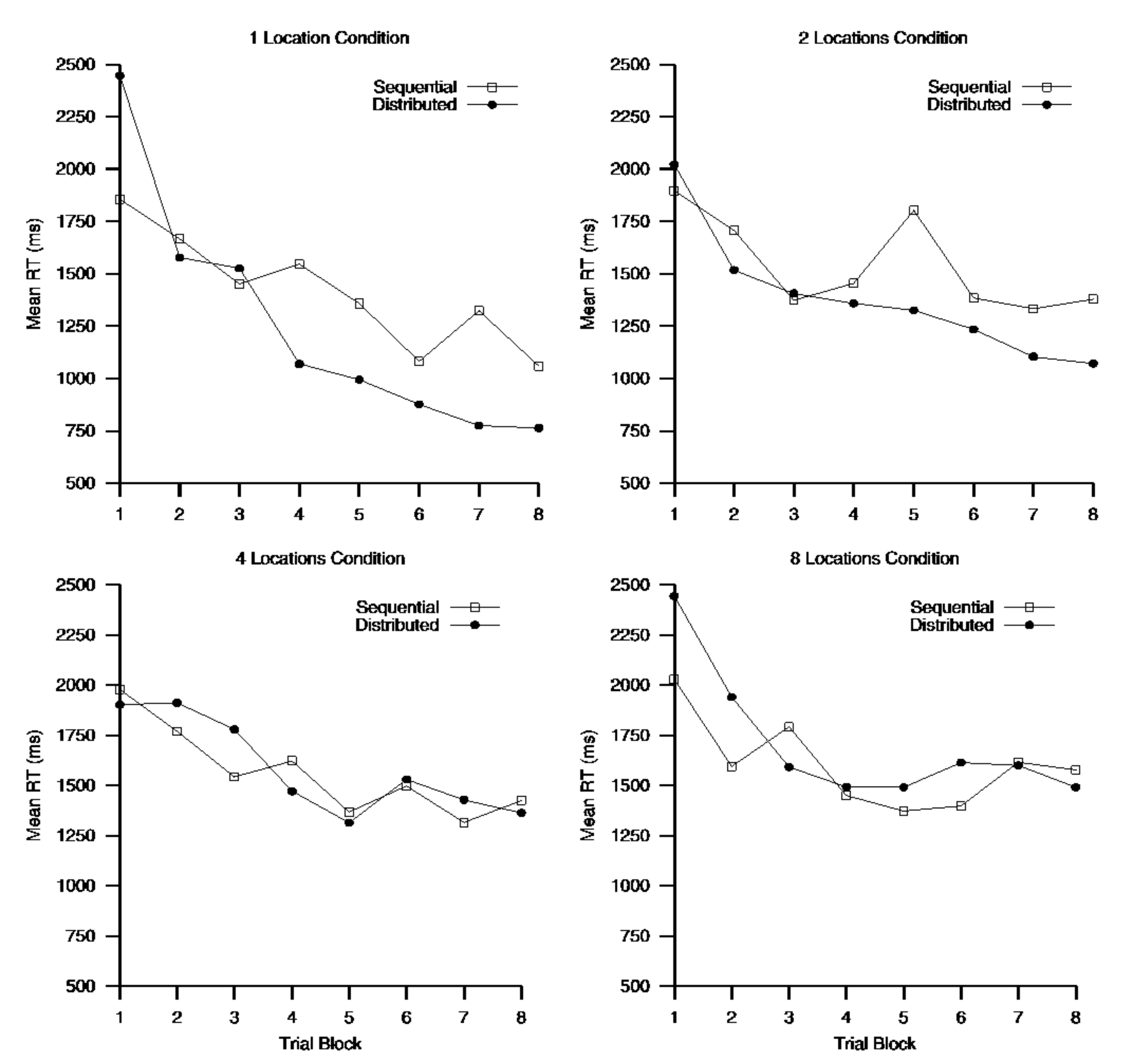
y = 137 * x + 925.3
2500
2000
1500
1000
500
Mean RT (ms)
1
2
3
4
5
6
7
8
9
10
Number of Buttons Fixated



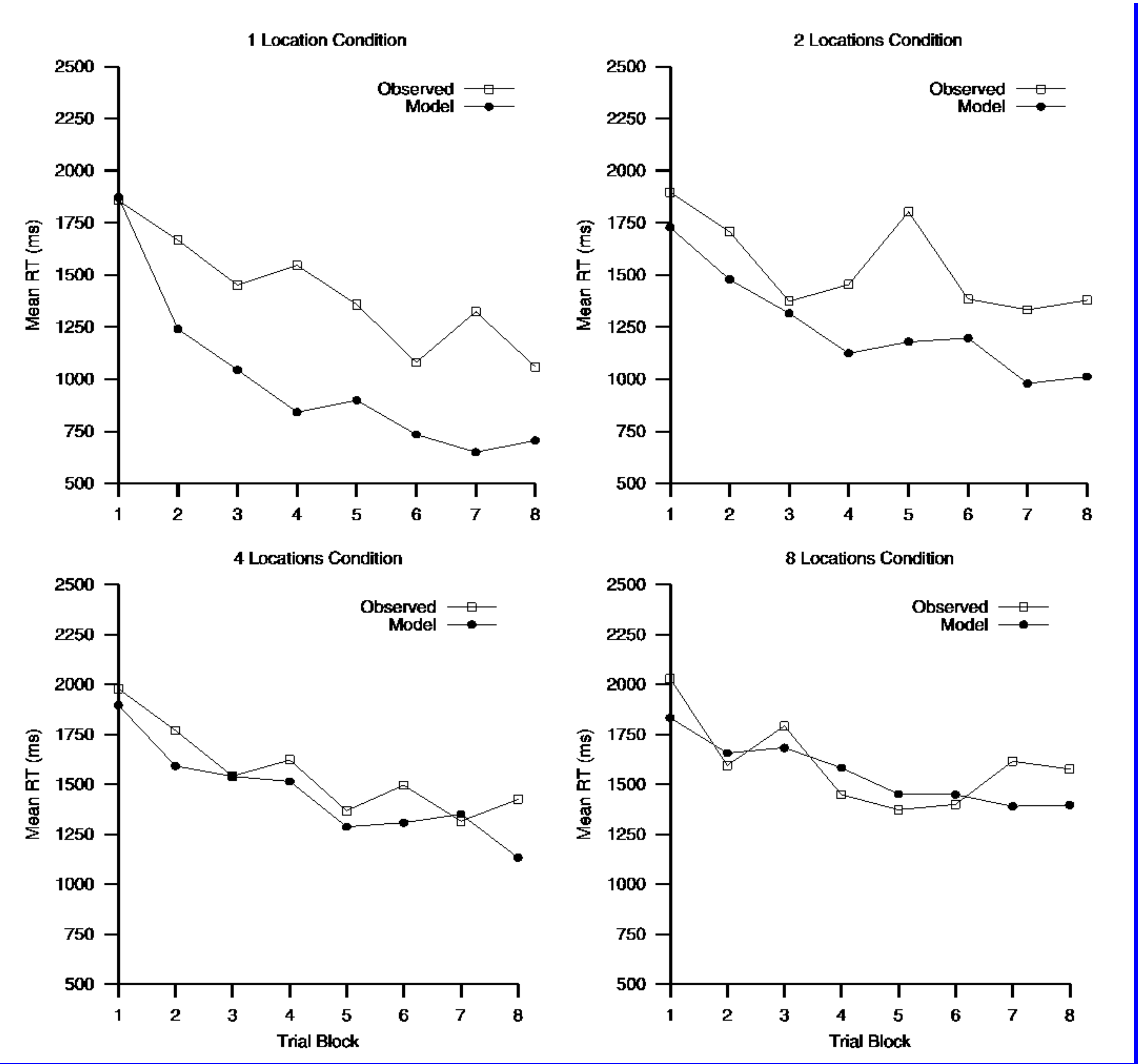
Mean model and observed button fixations, distributed condition ($R^2 = 0.73$)



Mean model and observed button fixations, sequential condition (R^2 = 0.73)



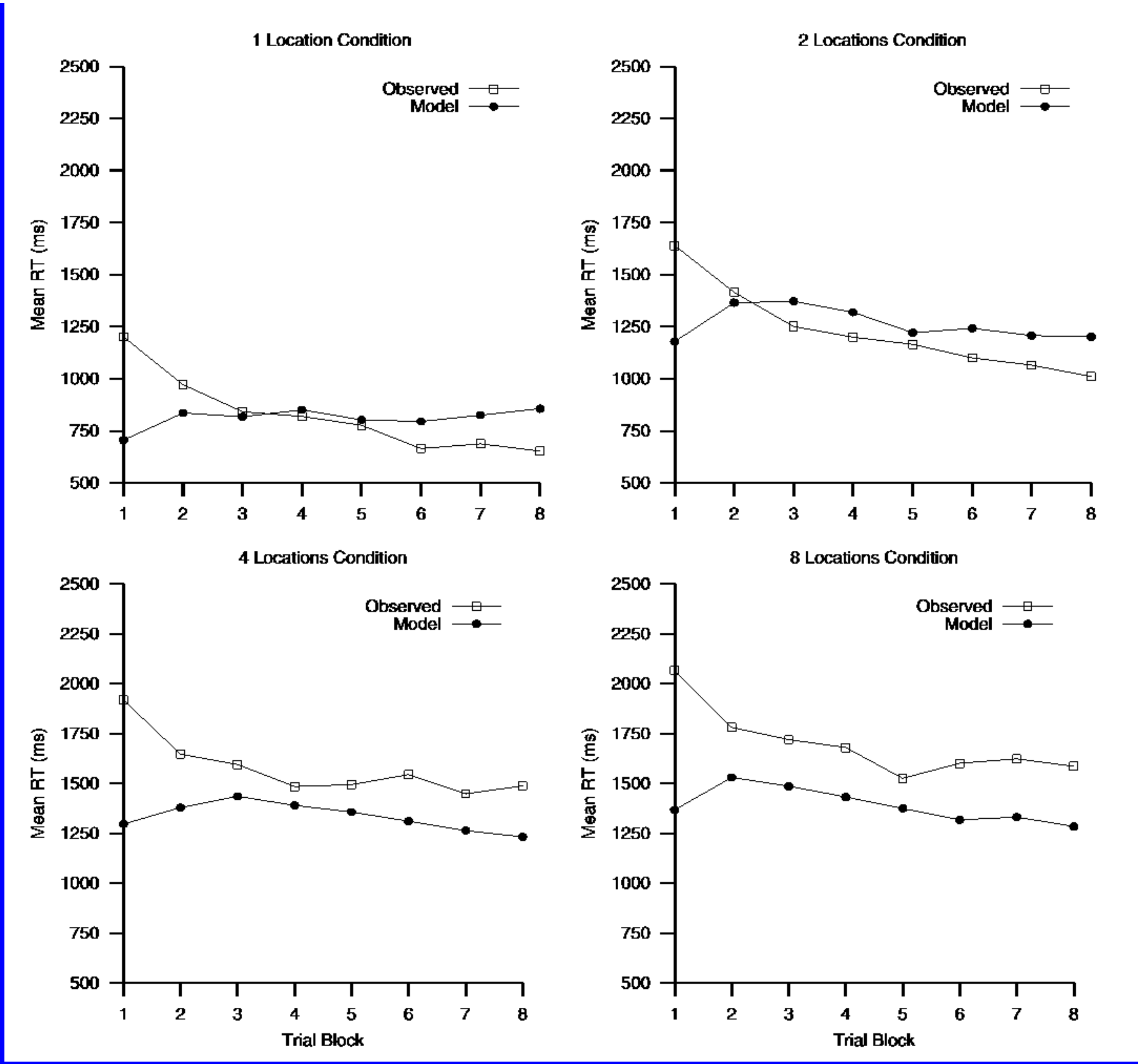
Observed search times averaged over first presentation in a block



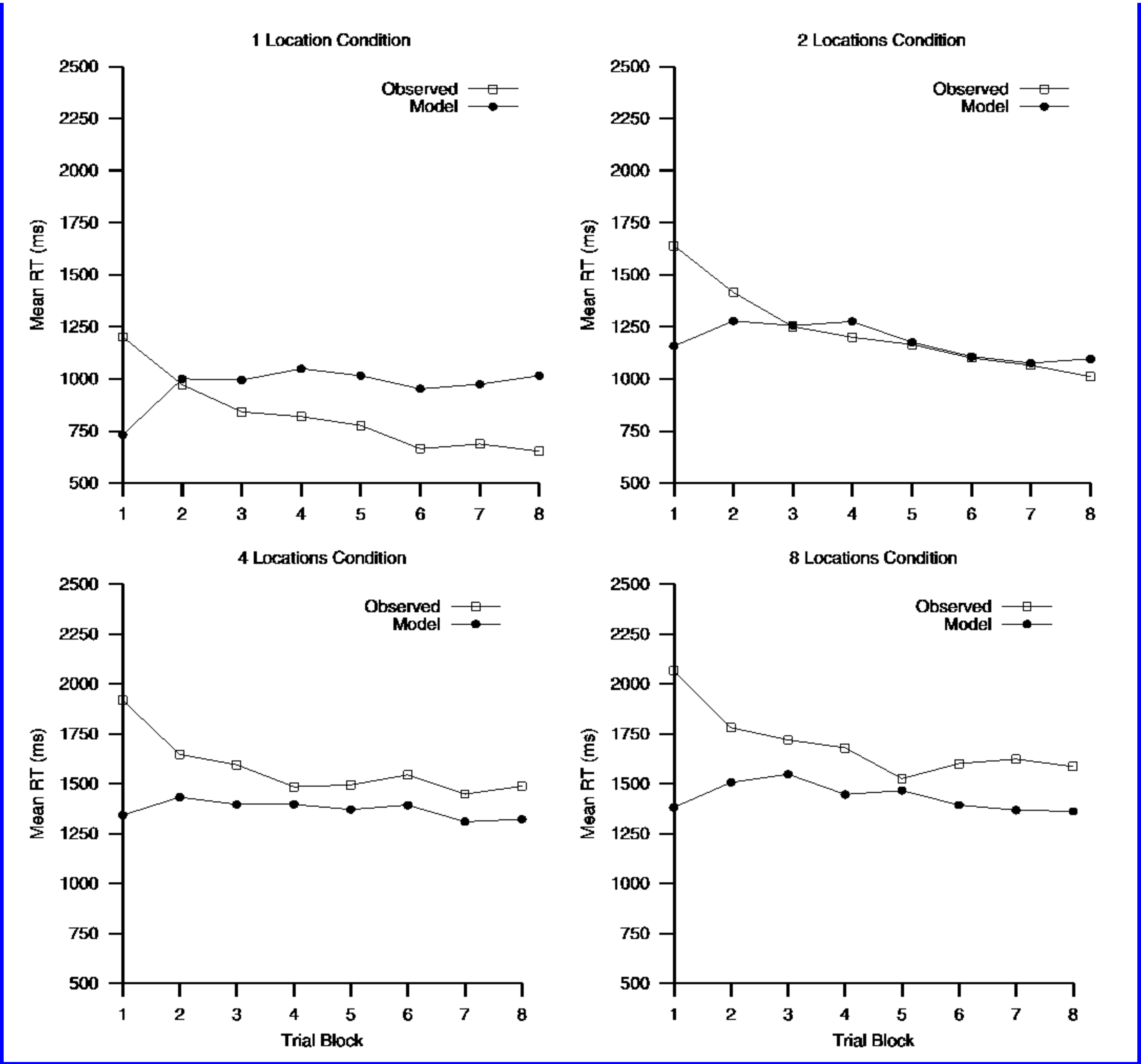
Mean observed and model search times, first block presentation, sequential condition (R^2 = -0.74)

Explaining the sequential data

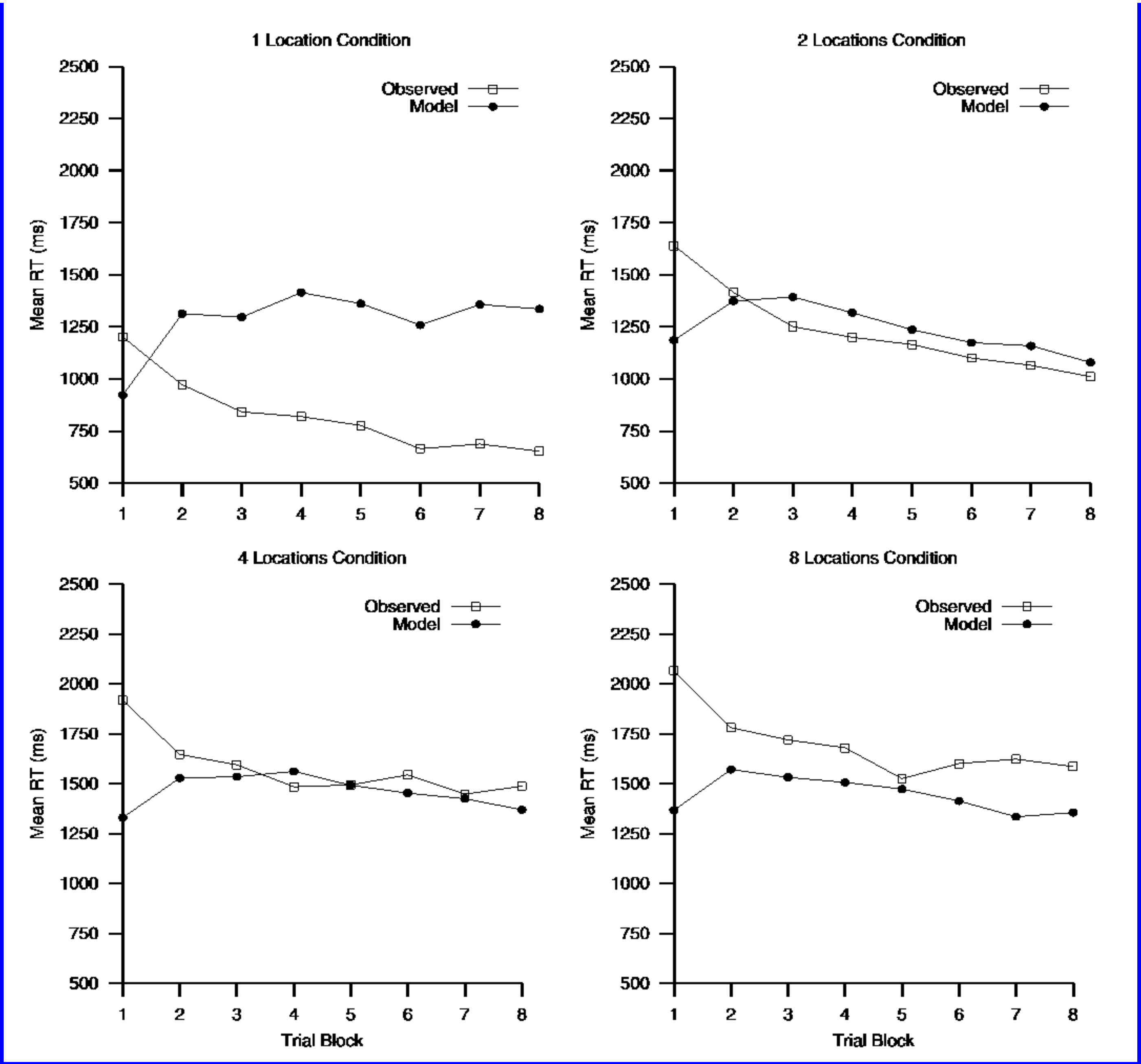
- Perhaps in the sequential condition, participants adopt a different strategy when they realise that the target letter is repeatedly at the same location.
- They don’t try to recall the goal chunk after a certain number of trials but just switch to a goal of clicking the same button until the target letter changes.
- New model version recognises if target letter has been found at the same location several trials (2, 3, 4) in a row, at which no retrieval is attempted and the model simply looks to the same location again. When the trial is completed, the goal is not used to strengthen the goal to be retrieved.



Goal change after 2 similar locations



Goal change after 3 similar locations



Goal change after 4 similar locations

Conclusions (so far…)

- People do learn location information simply as a result of interacting with stimuli.
- Limited to small number (< 4) of locations.
- Presentation format significantly affects the learning of location information.
- A simple ACT-R model (10 productions with minor parameter adjustments) provides a close fit to much of the learning and eye movement data from both fromat conditions.
- Model search times currently too fast for sequential condition. Work in progress...

Thanks to...

Dan Bothel & Mike Byrne for rapid responses to my email requests for help.