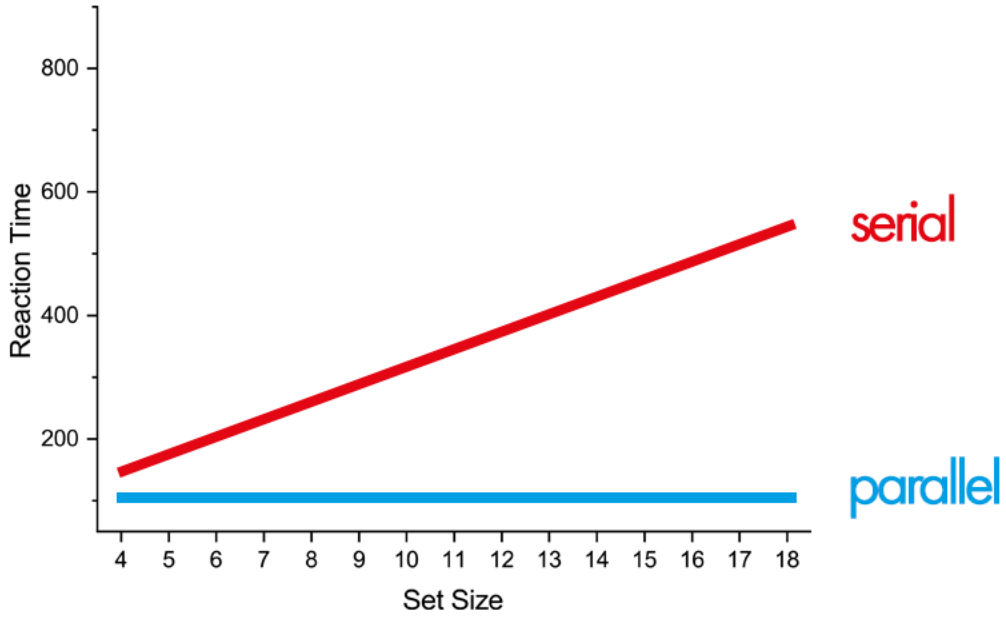
Demystifying Visual Search

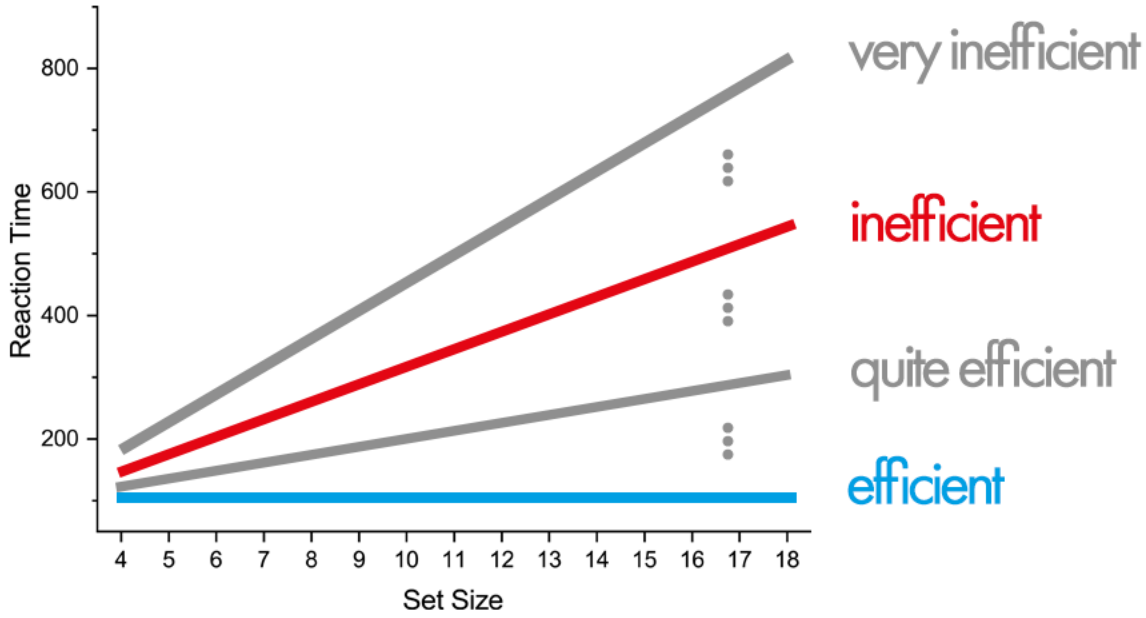
23.08.2023

Raul Grieben

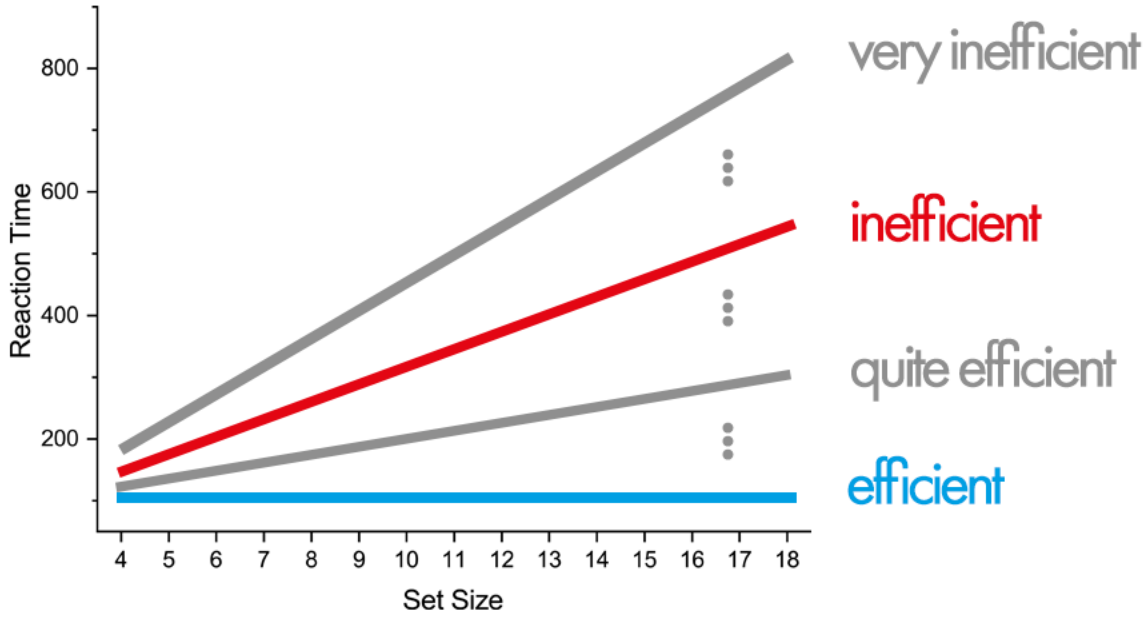
Basic Terminology



In the classical view of Anne **Treisman**, visual **search** was either **parallel** or **serial**.

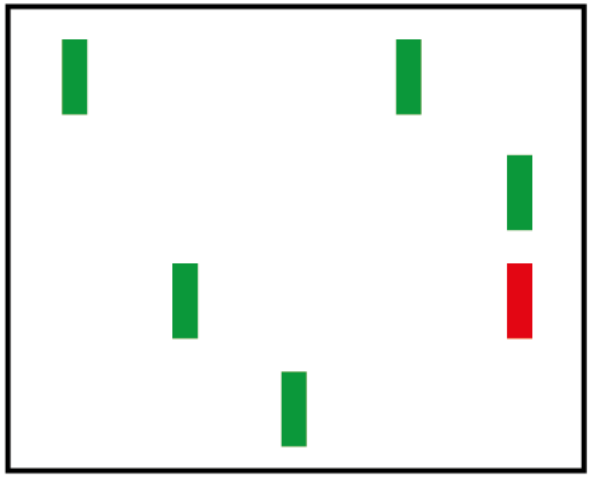


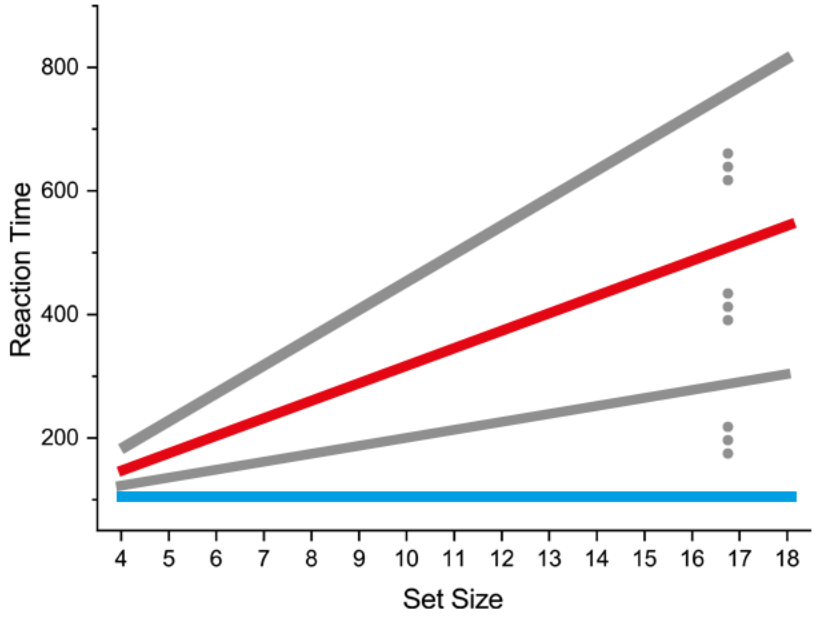
Jeremy **Wolfe**, on the other hand, described the **efficiency** of visual **search** as forming a **continuum**.



He defined the **slope** of the RT against set size function as the **measure** of **efficiency**.

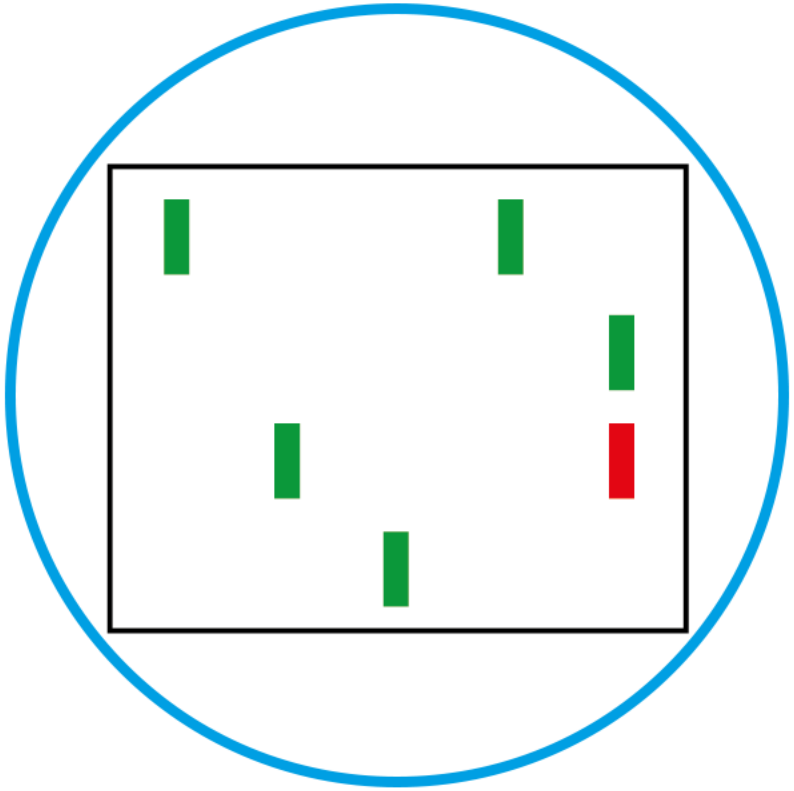
single feature search



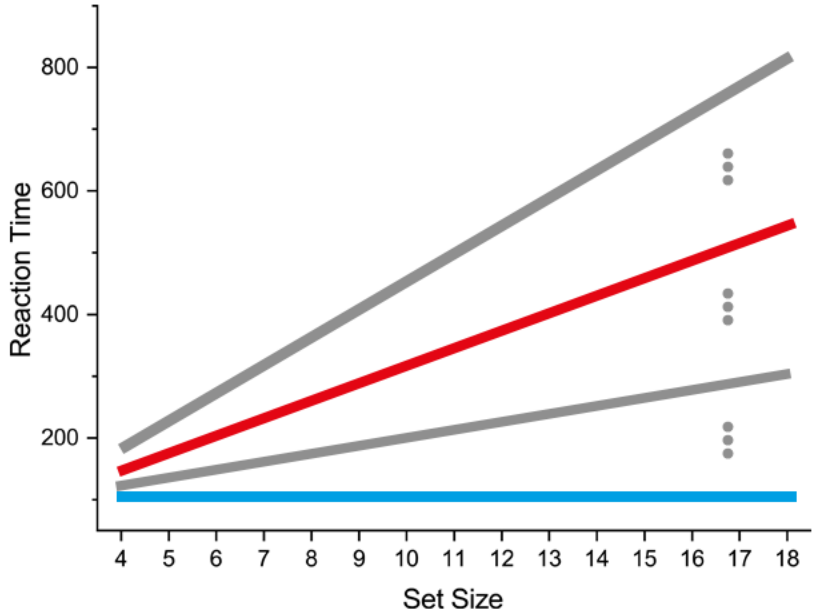


By this measure, single **feature search** is **efficient** as the reaction times are **independent** of **set size**.

single feature search

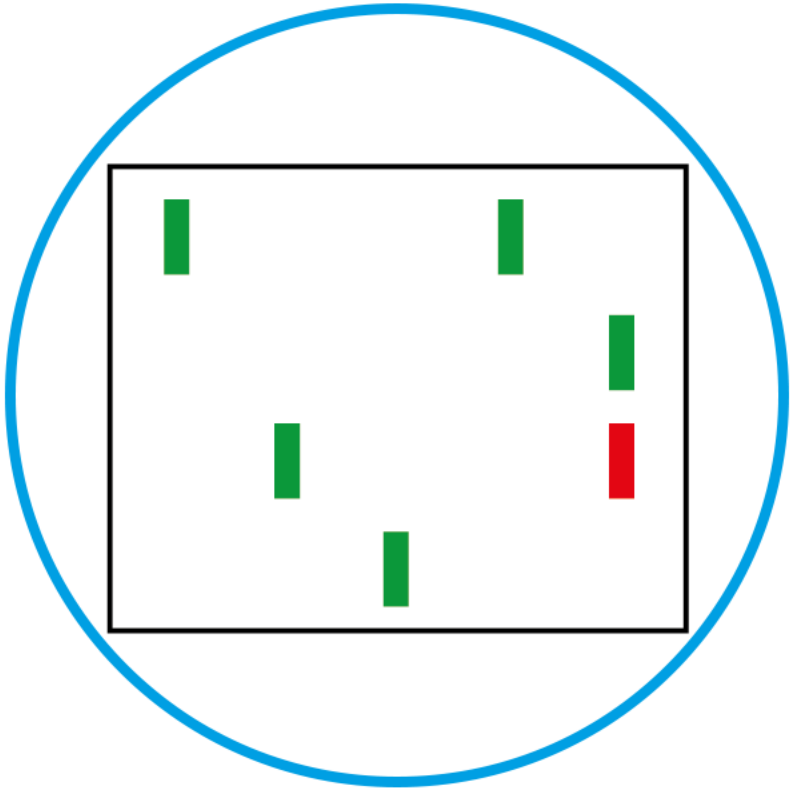


efficient

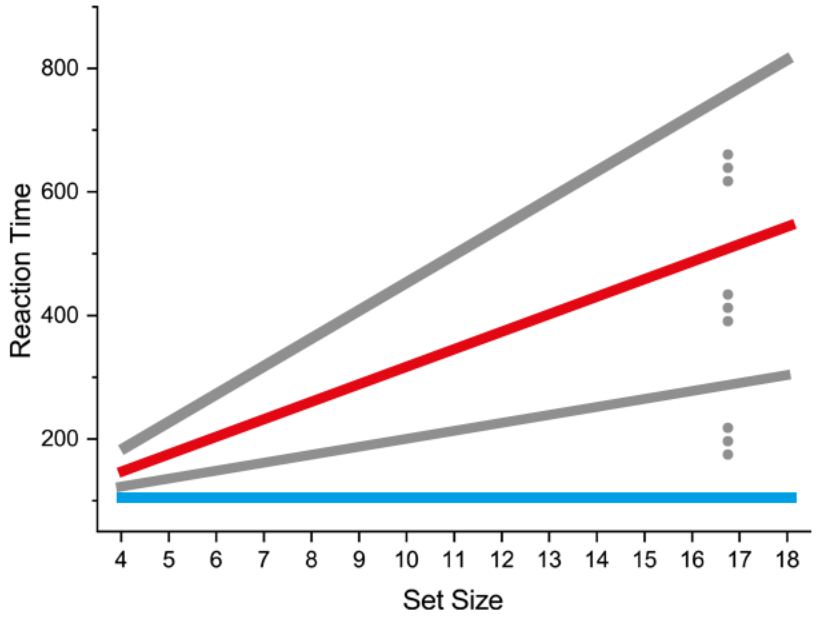


The **target pops out**.

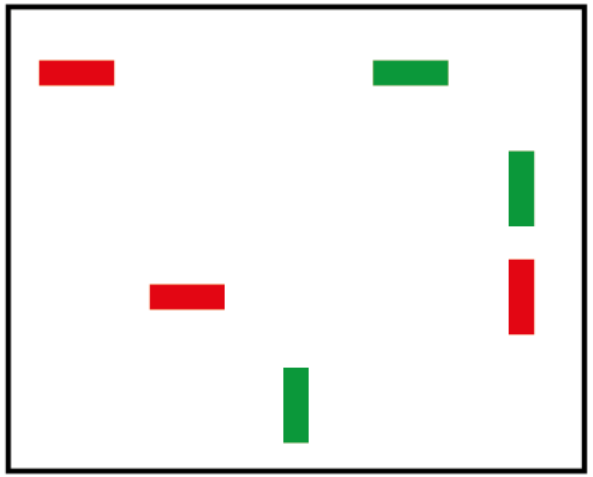
single feature search



efficient

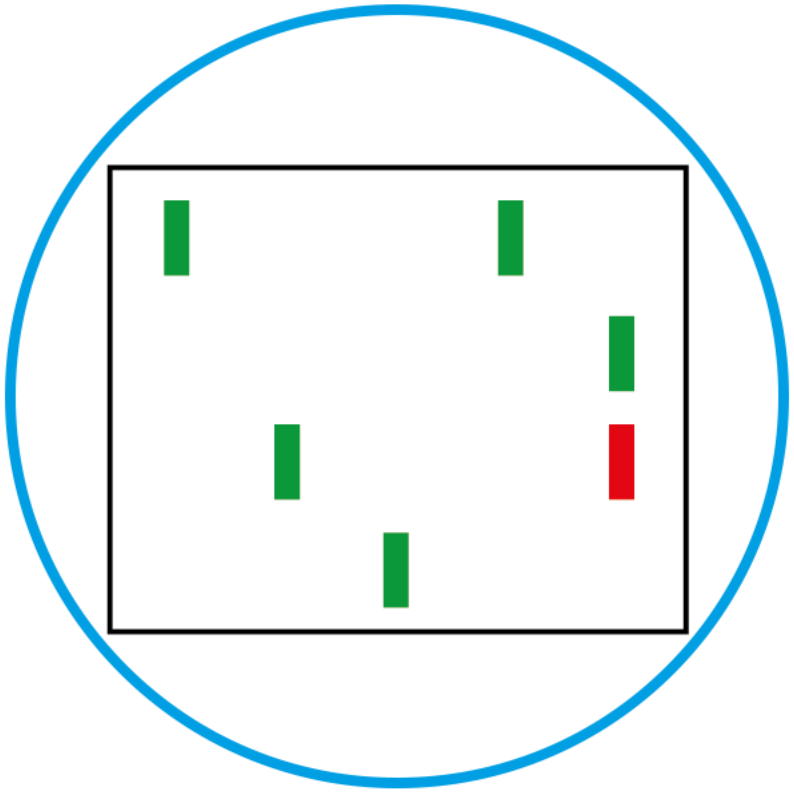


conjunctive search

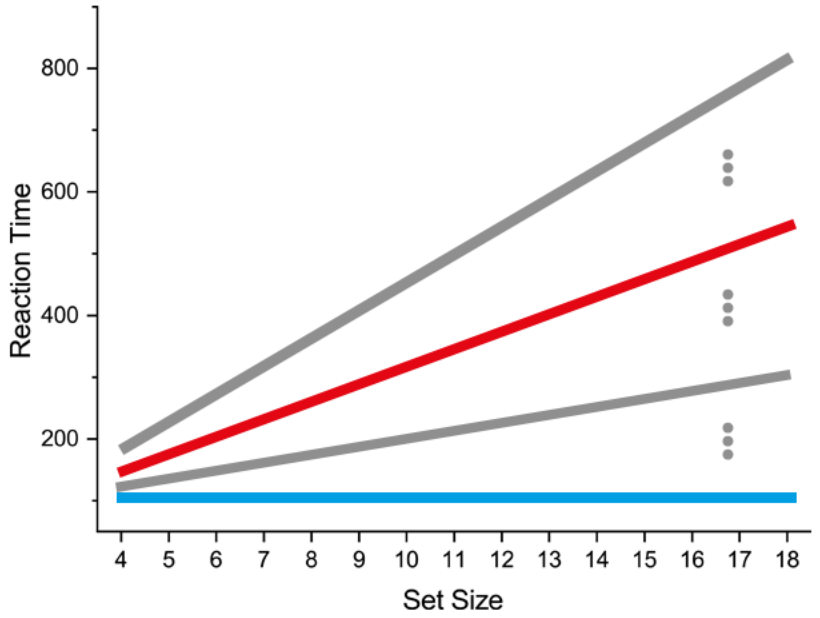


In the **conjunctive** condition RTs are **proportional** to the number of **distractor items**.

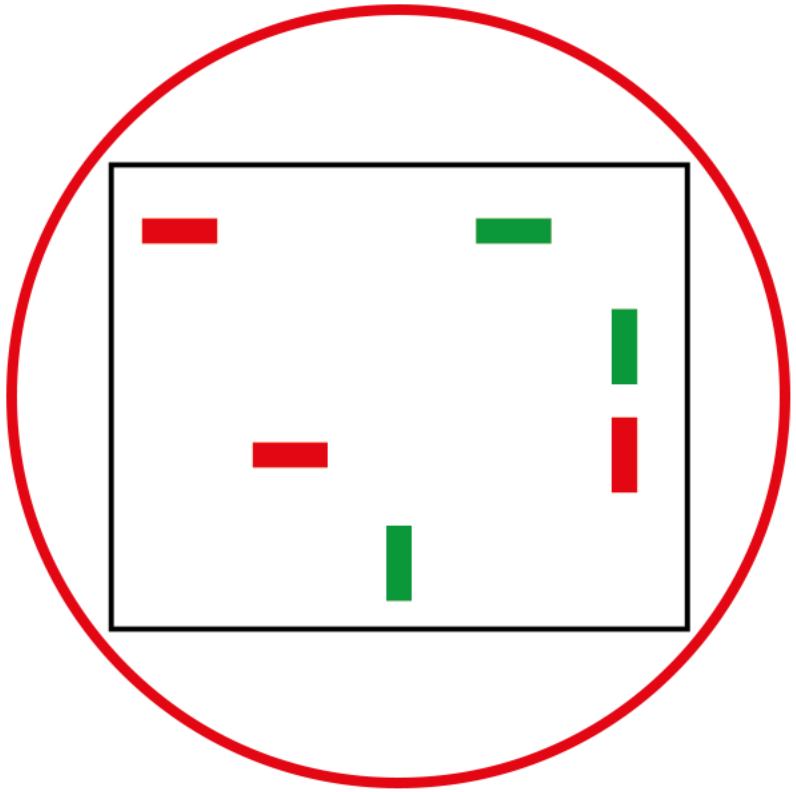
single feature search



efficient



conjunctive search



inefficient

Conjunctive search is, therefore, considered **inefficient**.

Understanding the interplay between bottom-up processing and top-down guidance in visual search

Bottom-Up and Top-Down Attention

- Attention can be categorized into two distinct functions

Bottom-up attention

Top-down attention

Bottom-Up and Top-Down Attention

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Bottom-up attention

- Attentional **guidance** driven purely by **external** factors

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- E.g., **local** feature **contrasts** like red/green or sudden movement

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- E.g., local feature contrasts like red/green or sudden movement
- Is the phylogenetically **older system**

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- Like prior **knowledge**, current **task** or goal, etc…

Bottom-Up and Top-Down Attention

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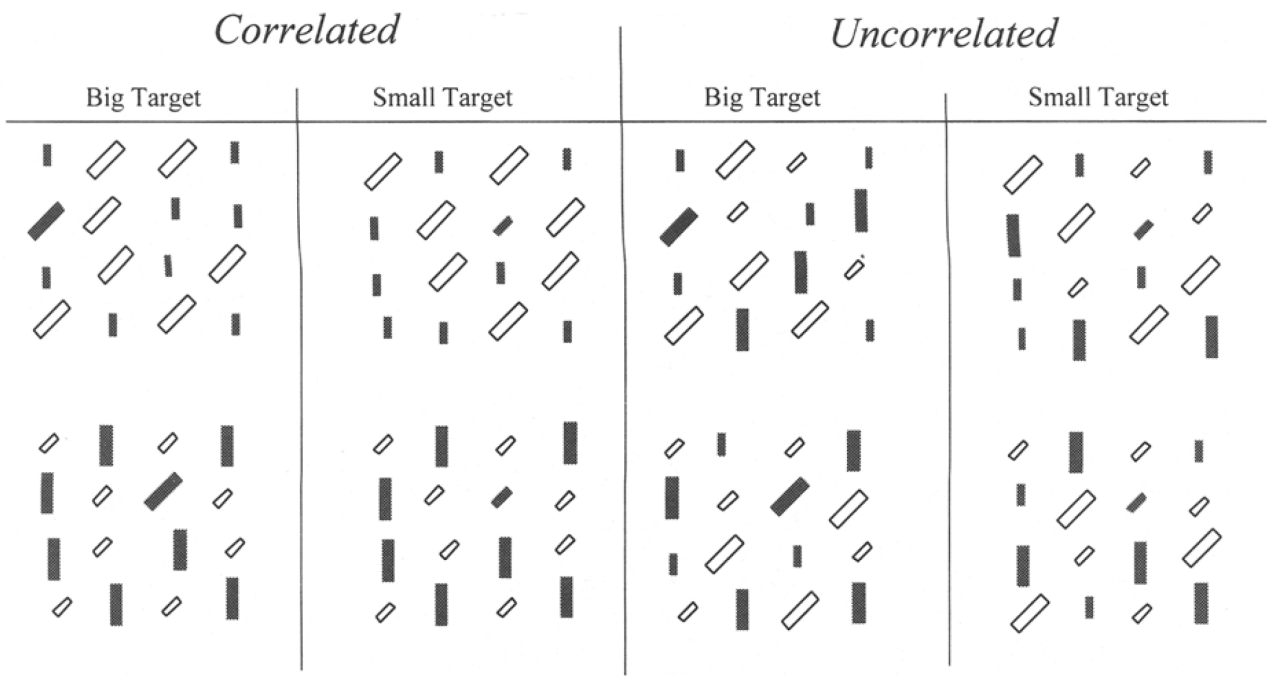
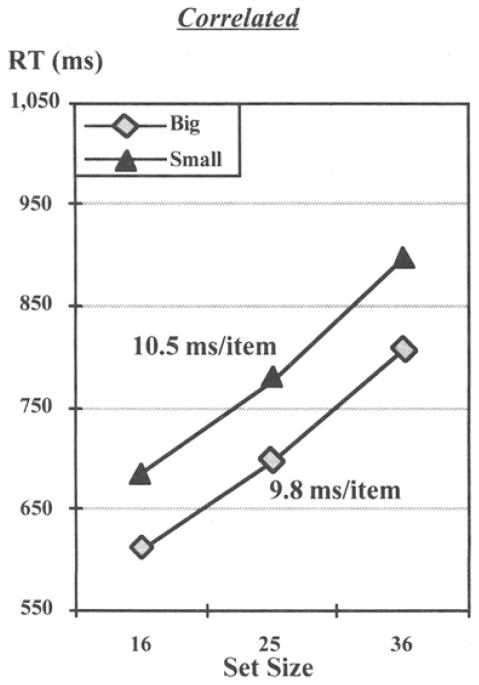
Top-down attention

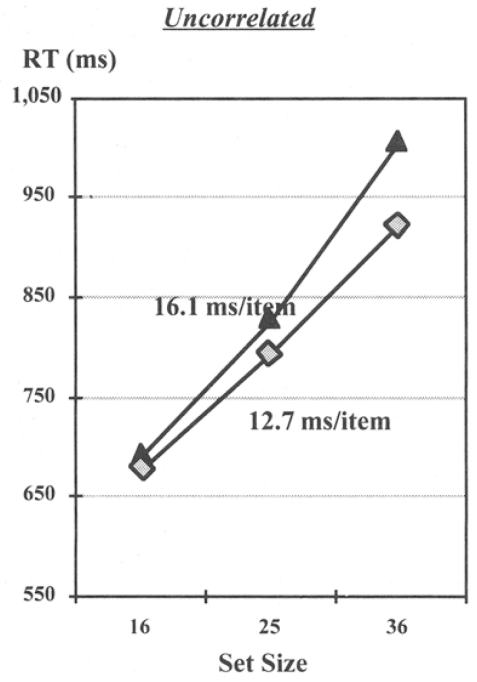
- Attentional guidance driven by internal factors
- Like prior knowledge, current task or goal, etc…
- **Guidance** of **visual search**: e.g. the location of a known object is unknown in the current scene

Is visual search a top-down or bottom-up process?

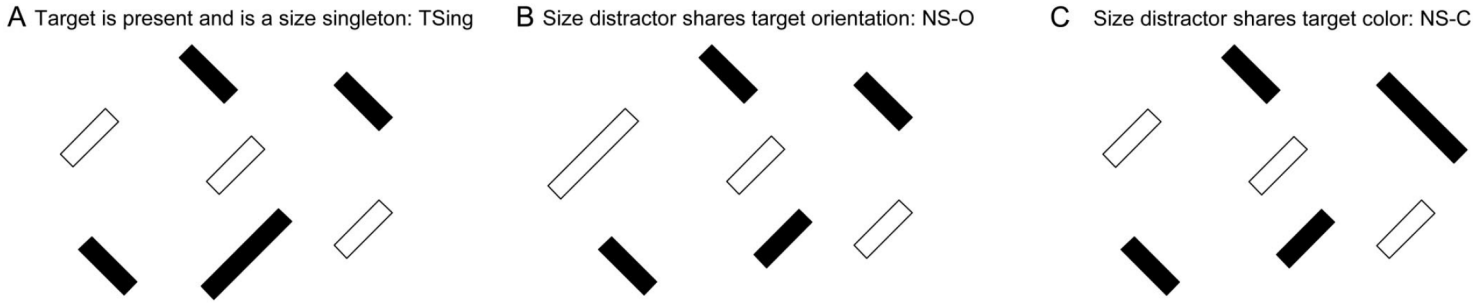
Found (1998) - Parallel coding of conjunctions in visual search

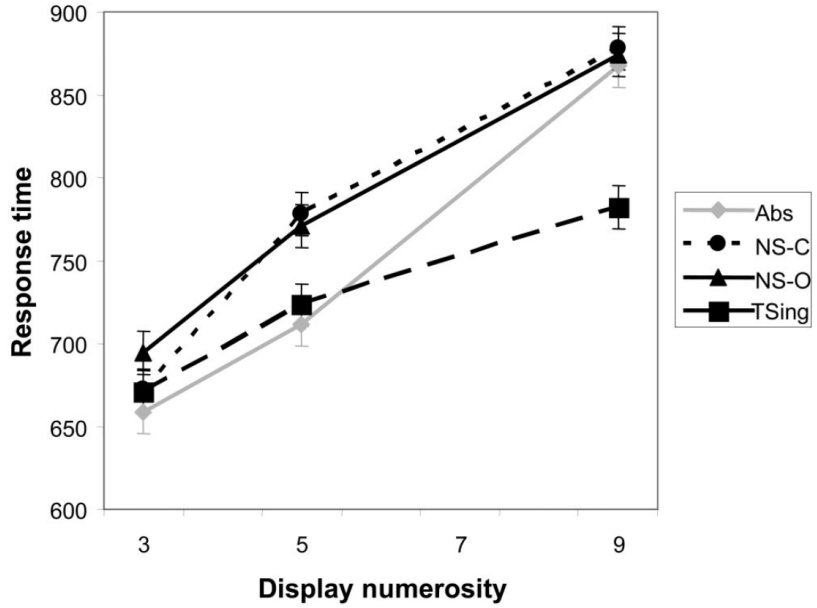




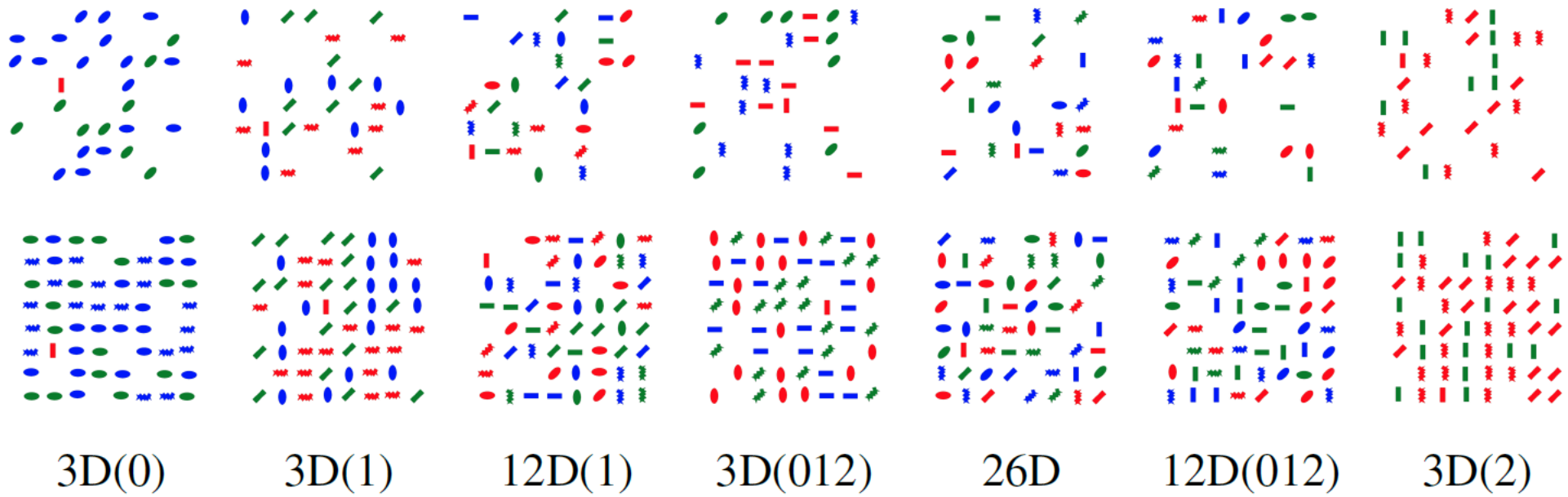


Proulx (2007) - Bottom-Up Guidance in Visual Search for Conjunctions





Nordfang and Wolfe (2014) - Guided search for triple conjunctions



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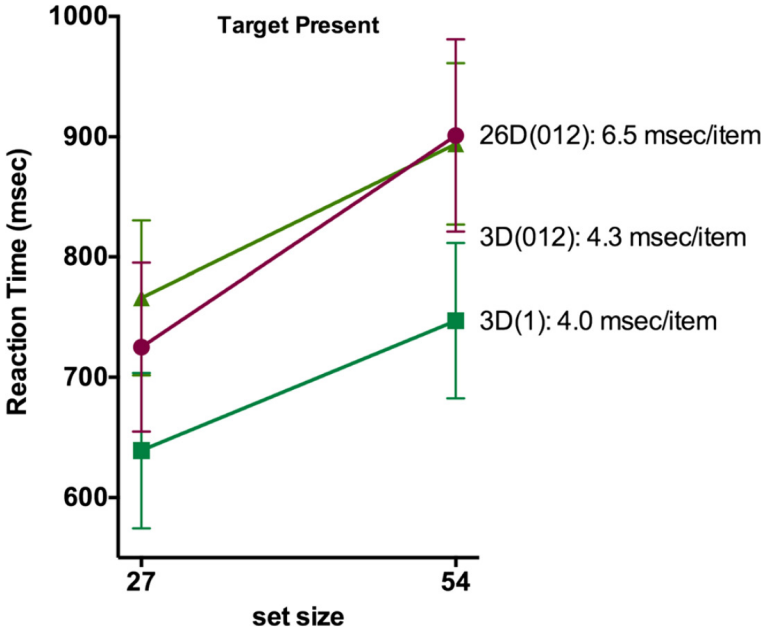
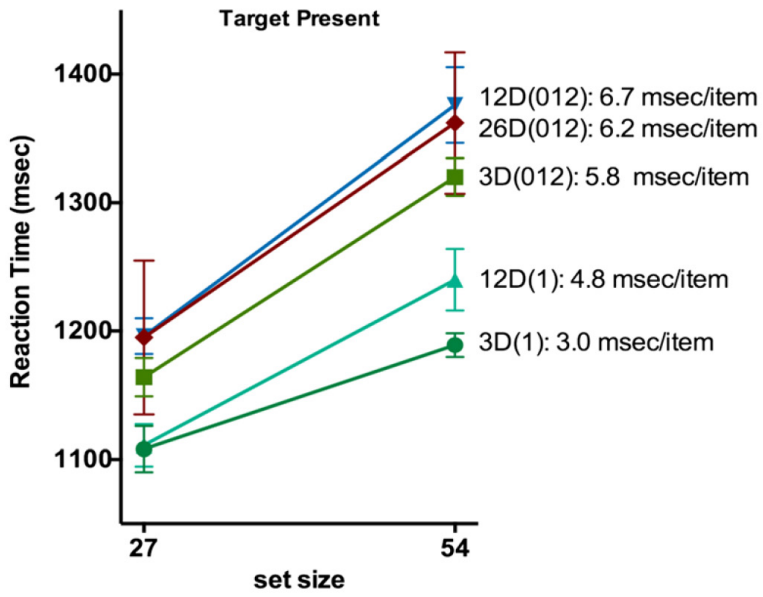
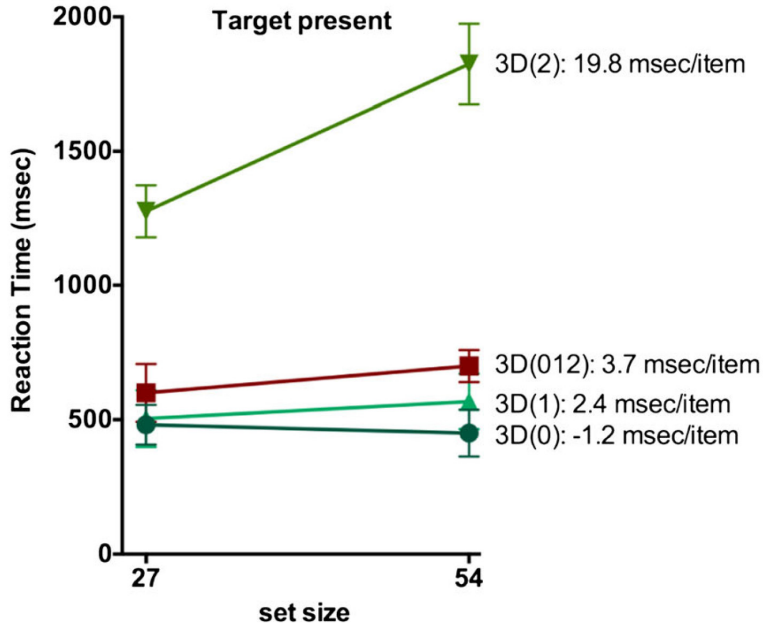


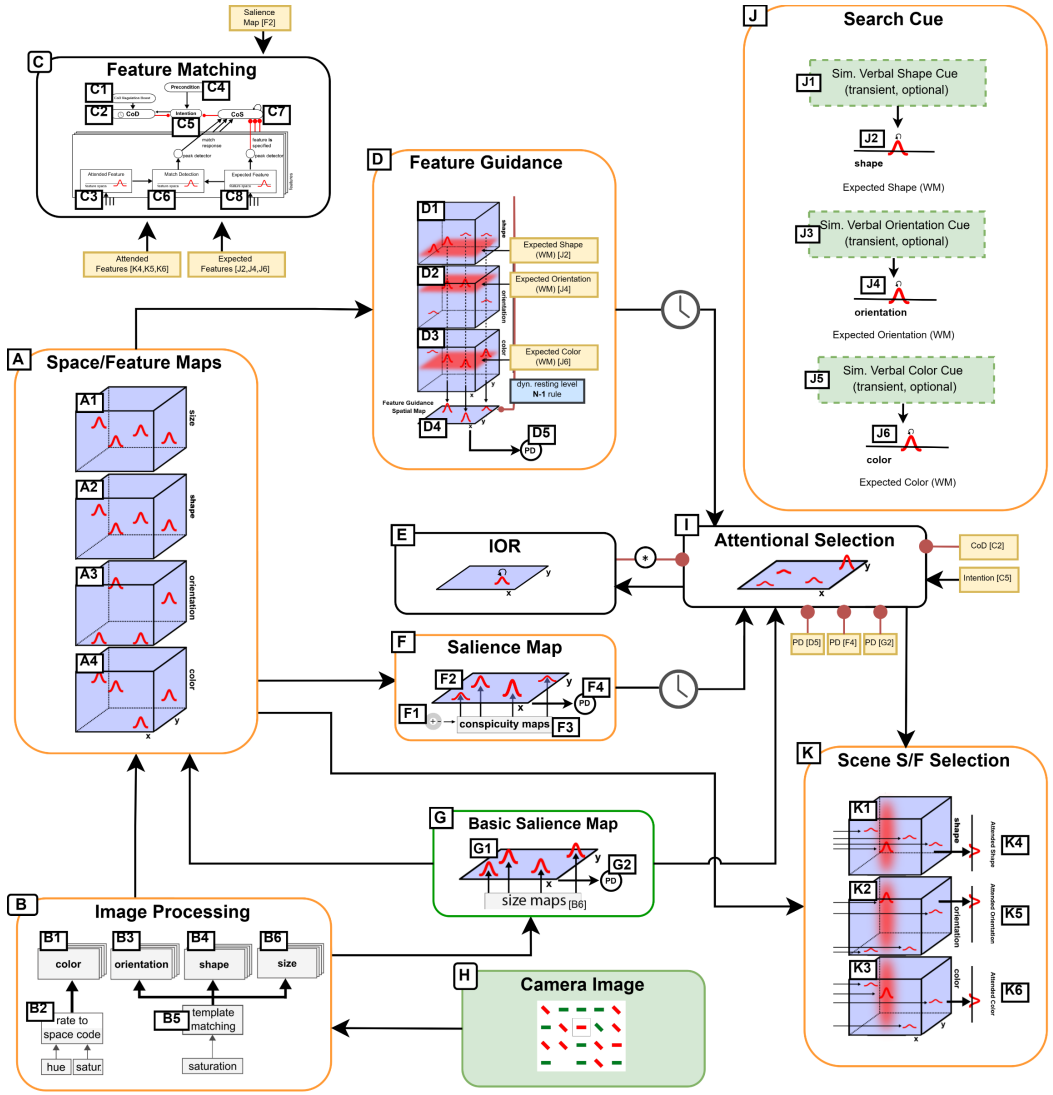




The interaction between a target of one type and different mixtures of distractors is systematic, but not trivial to Model.

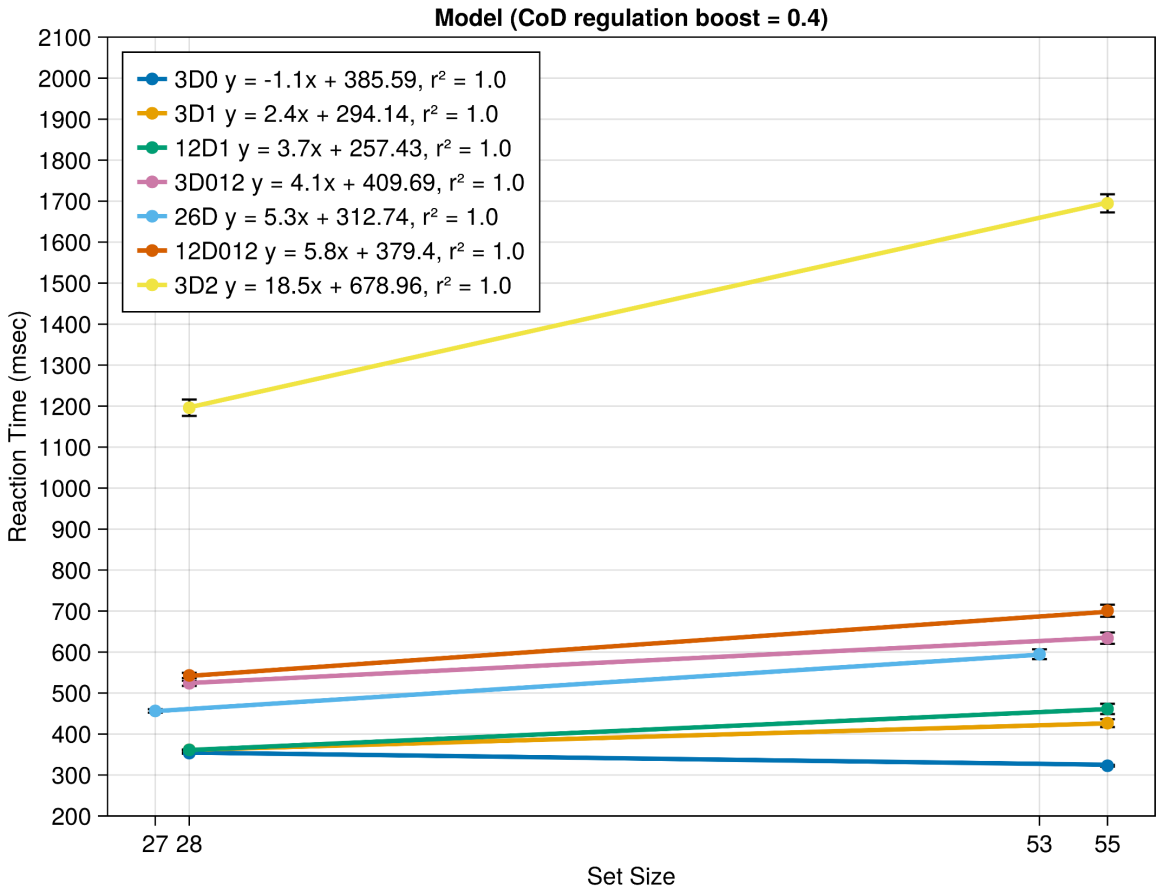
Nordfang and Wolfe (2014)

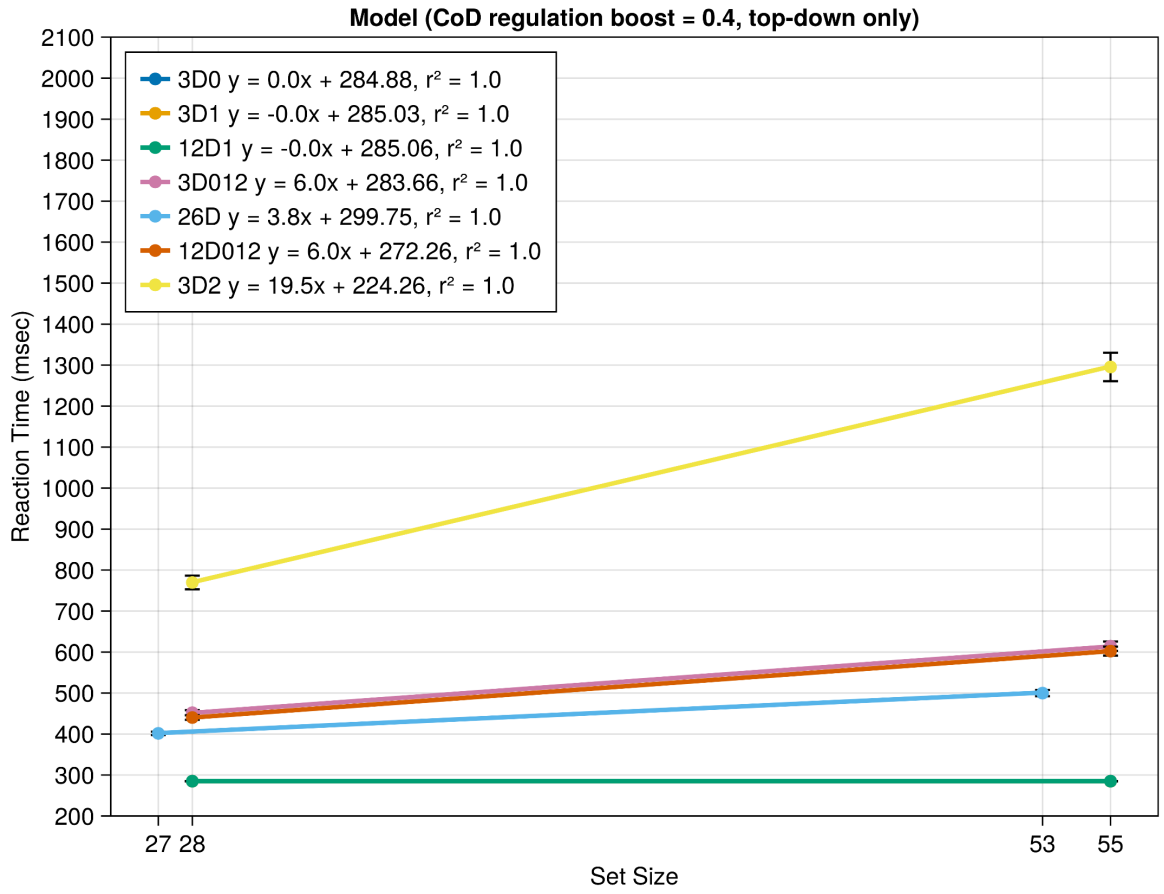
Model



Revised Version of Grieben, R., & Schöner, G. – *CogSci* 2021

Model Results - Nordfang and Wolfe (2014)





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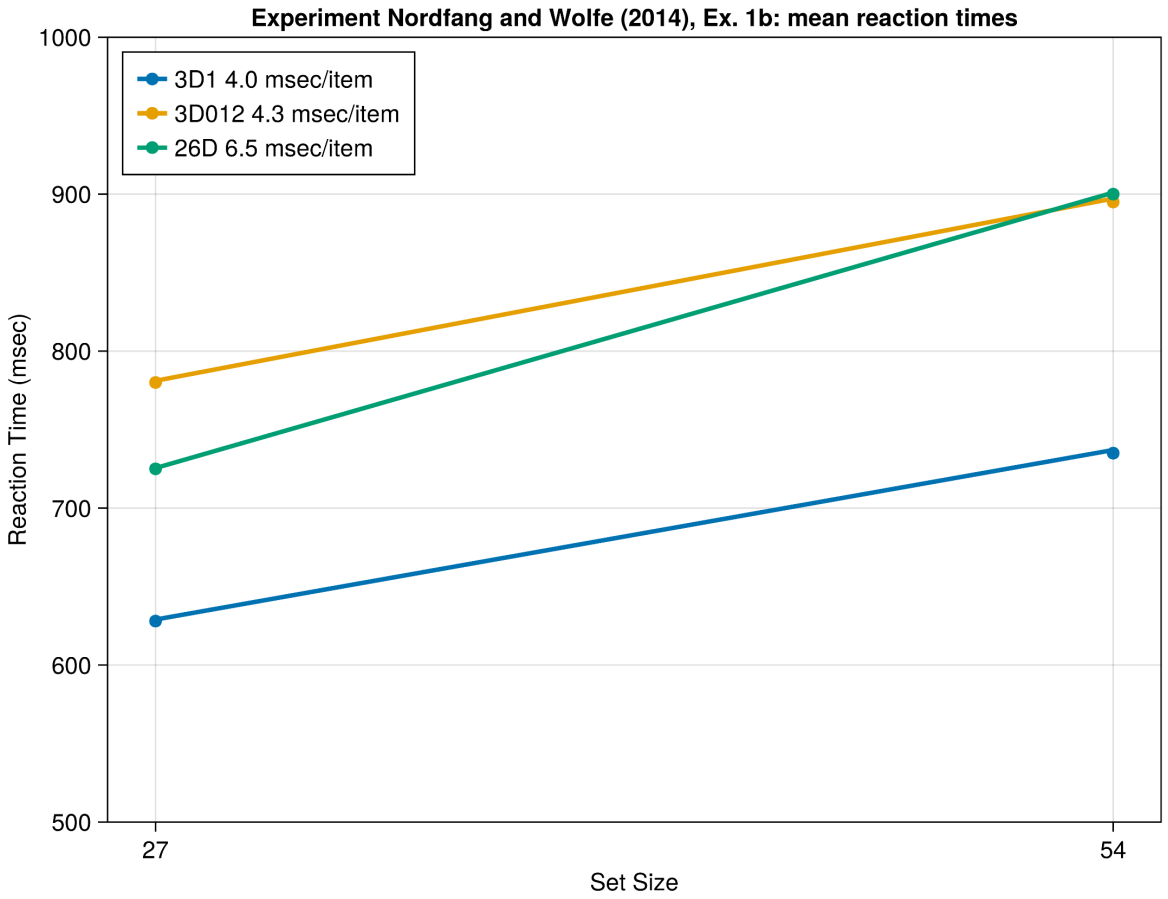

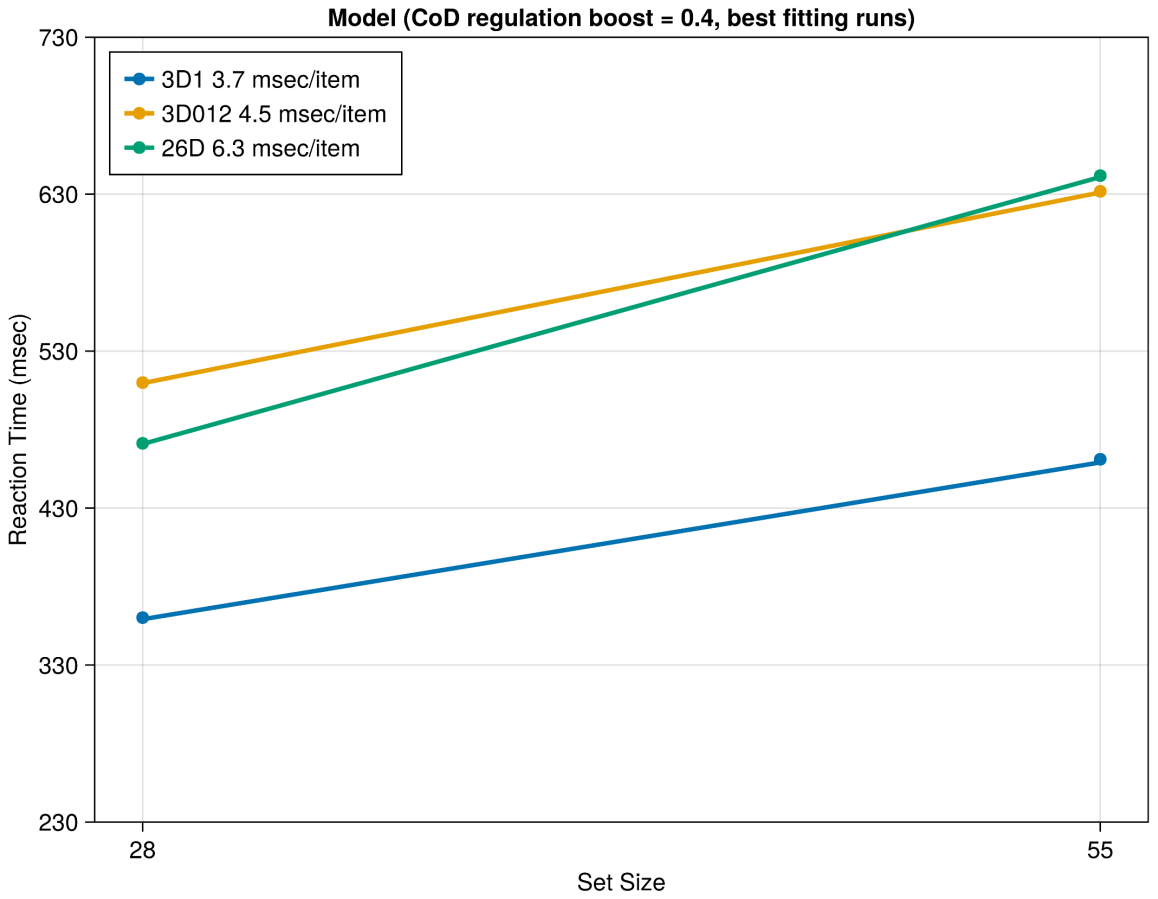

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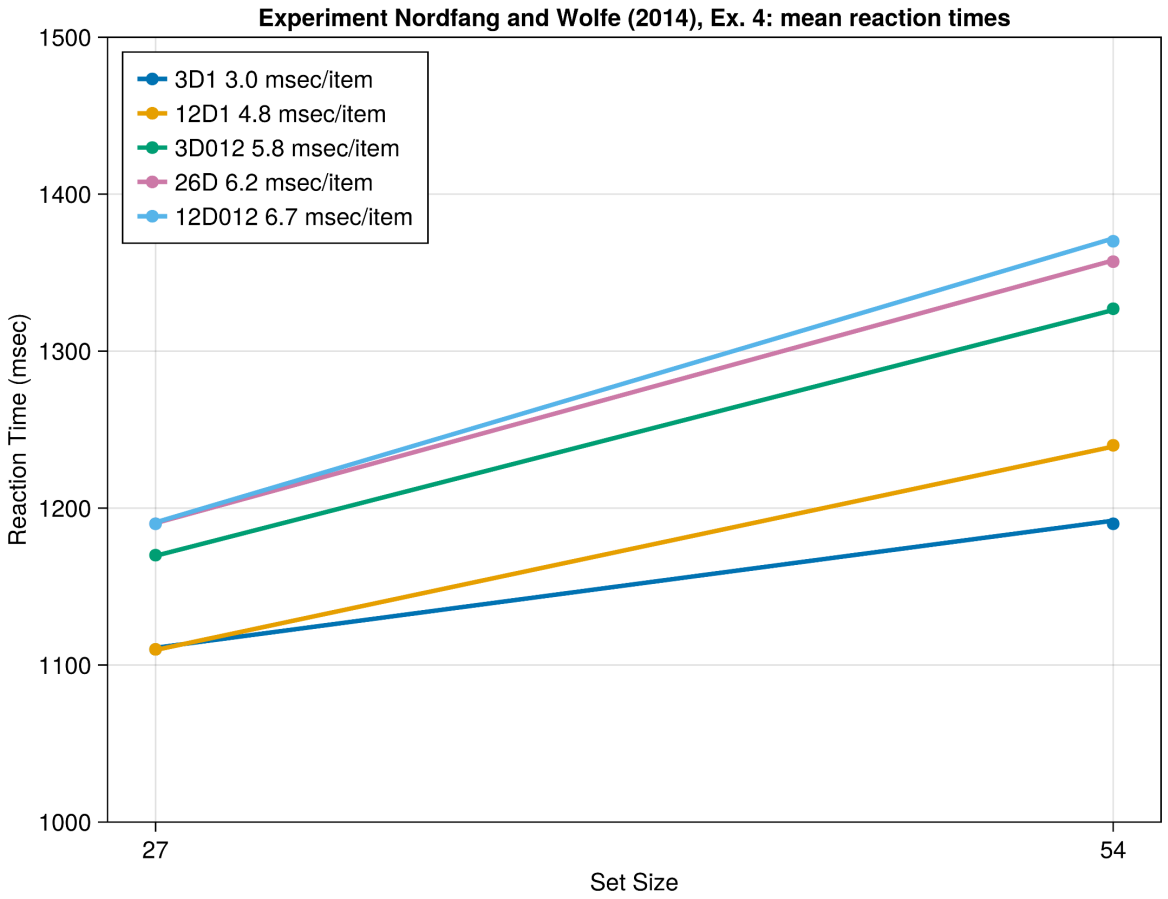

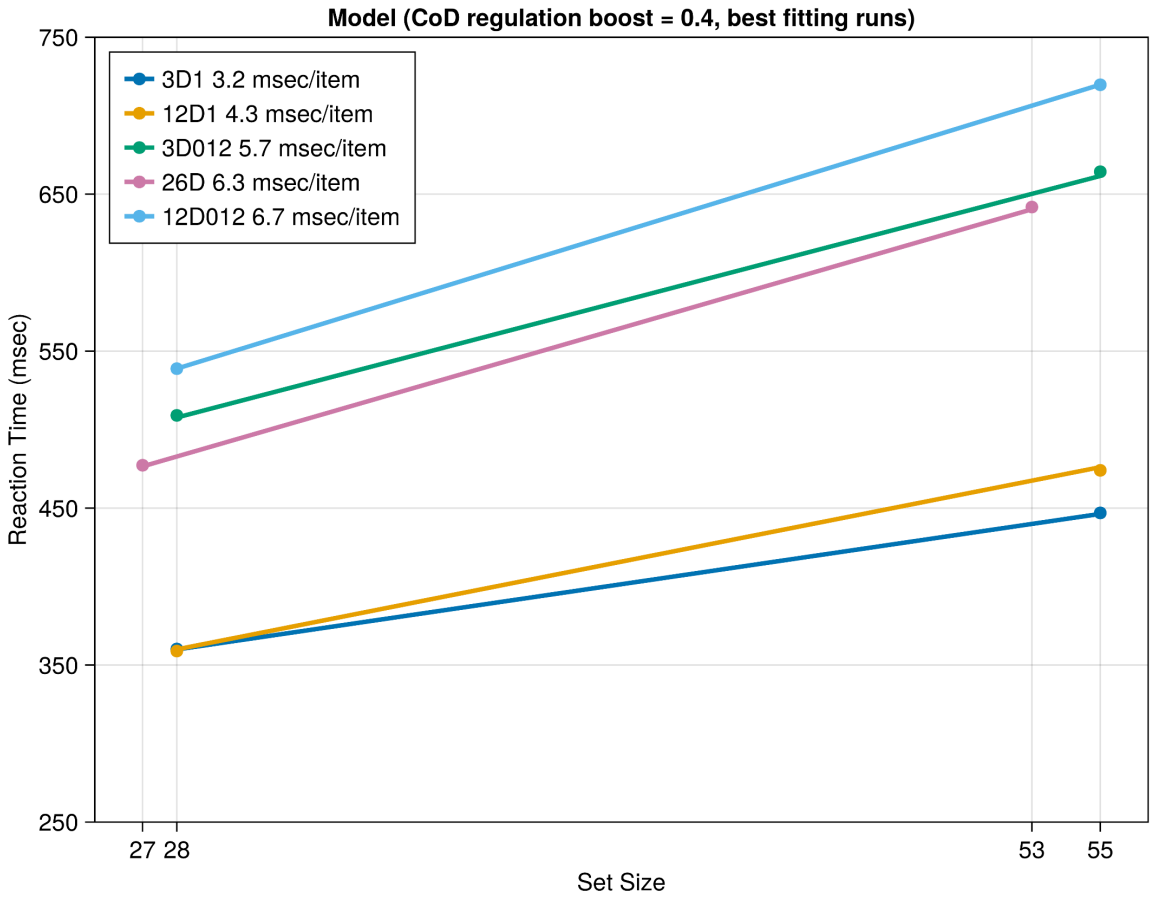

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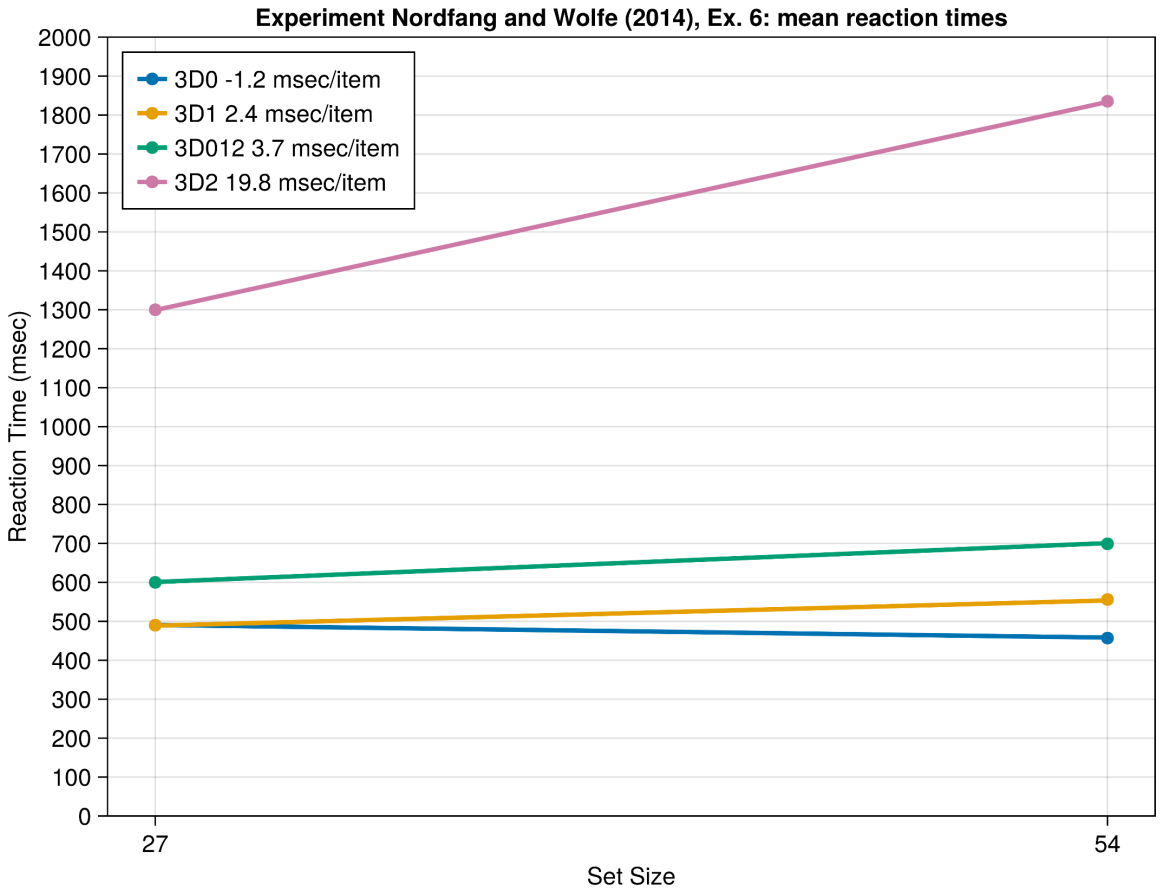
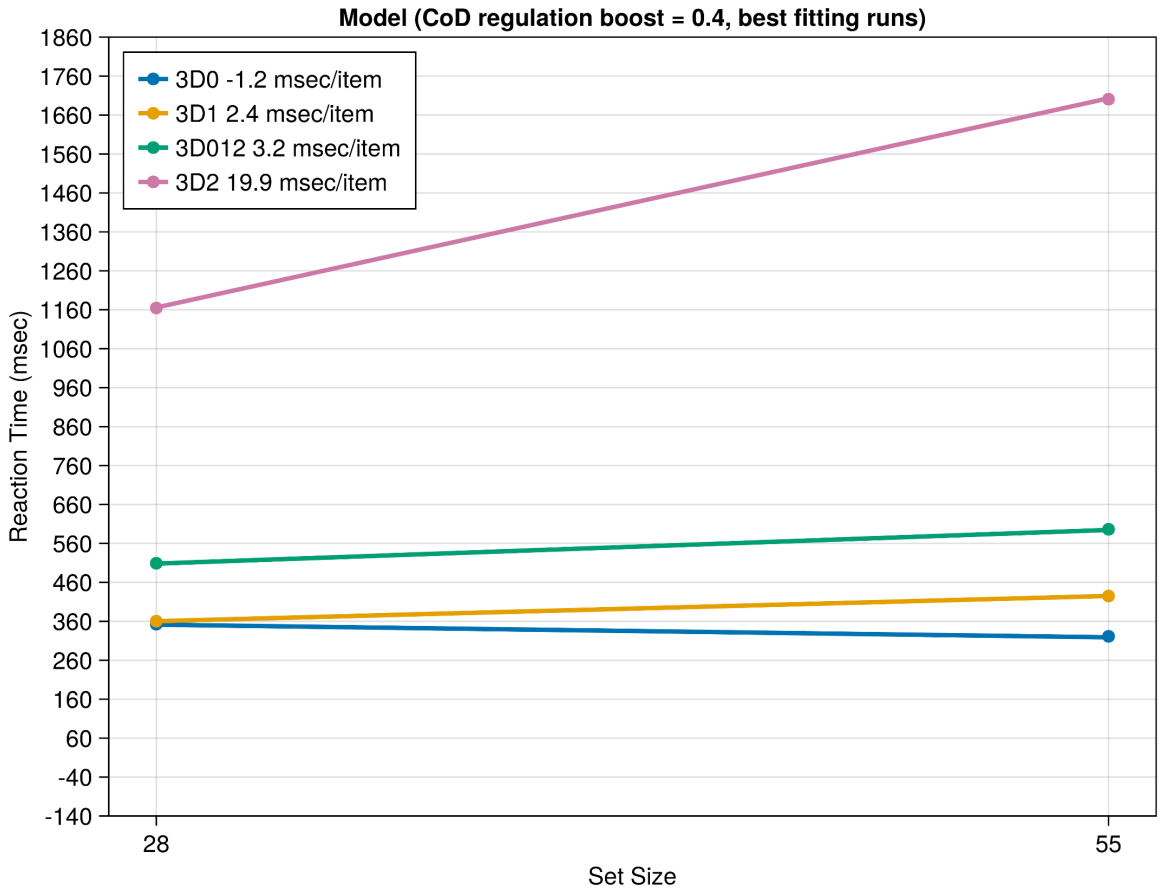
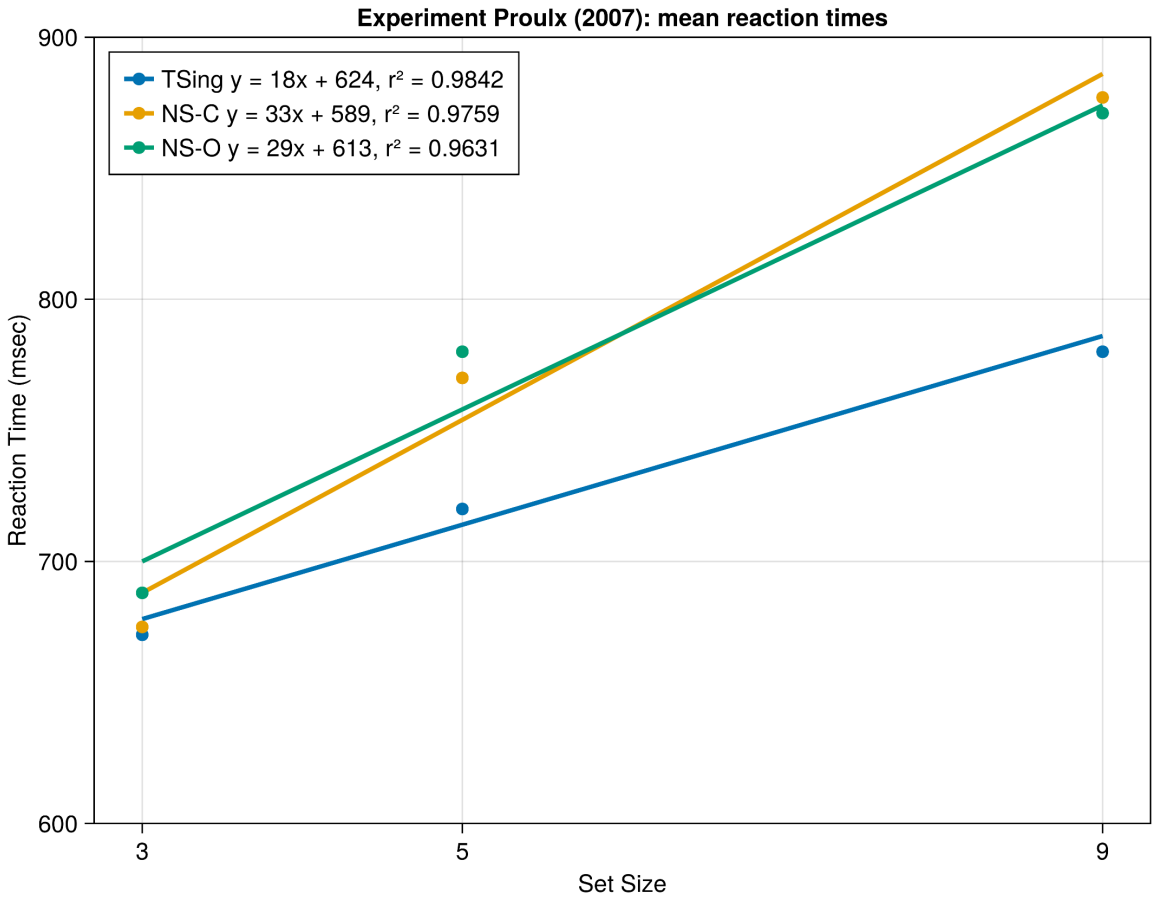
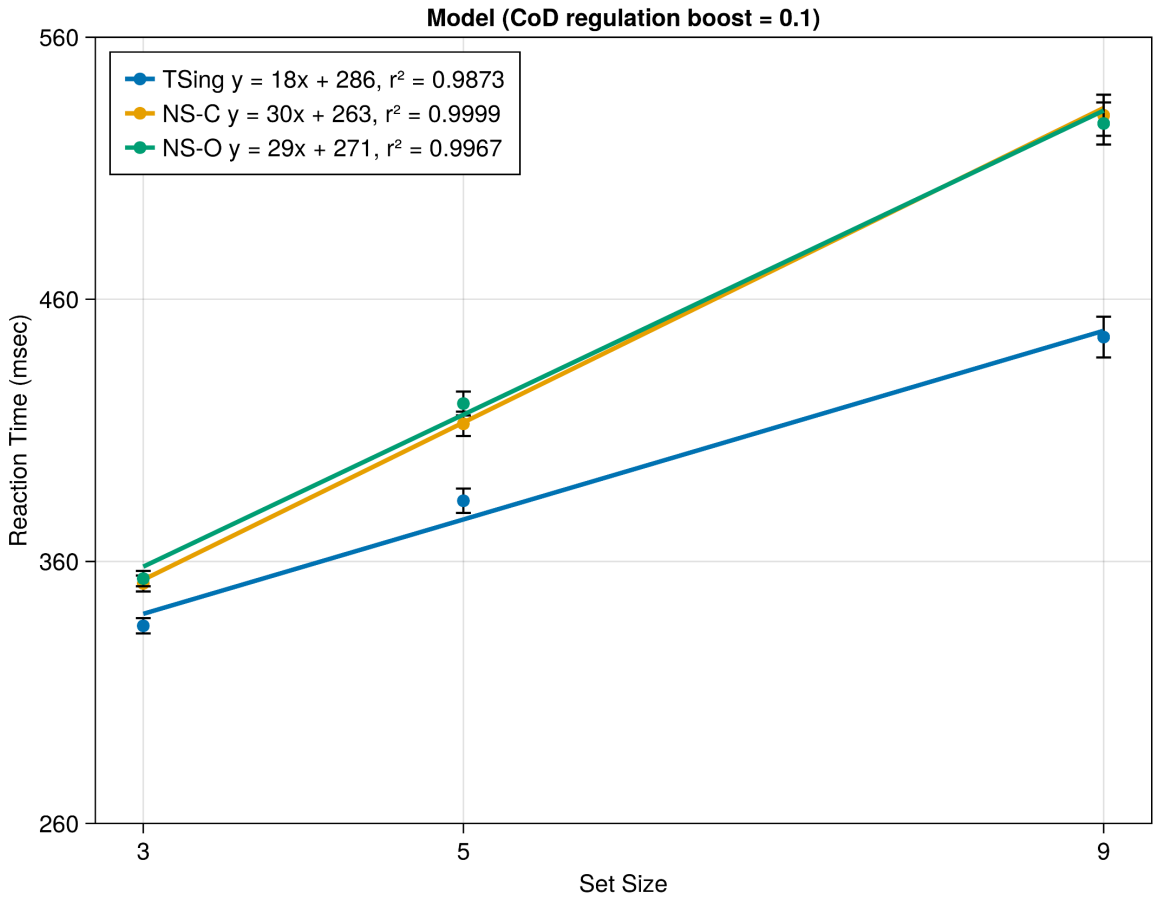




Model Results – Proulx (2007)





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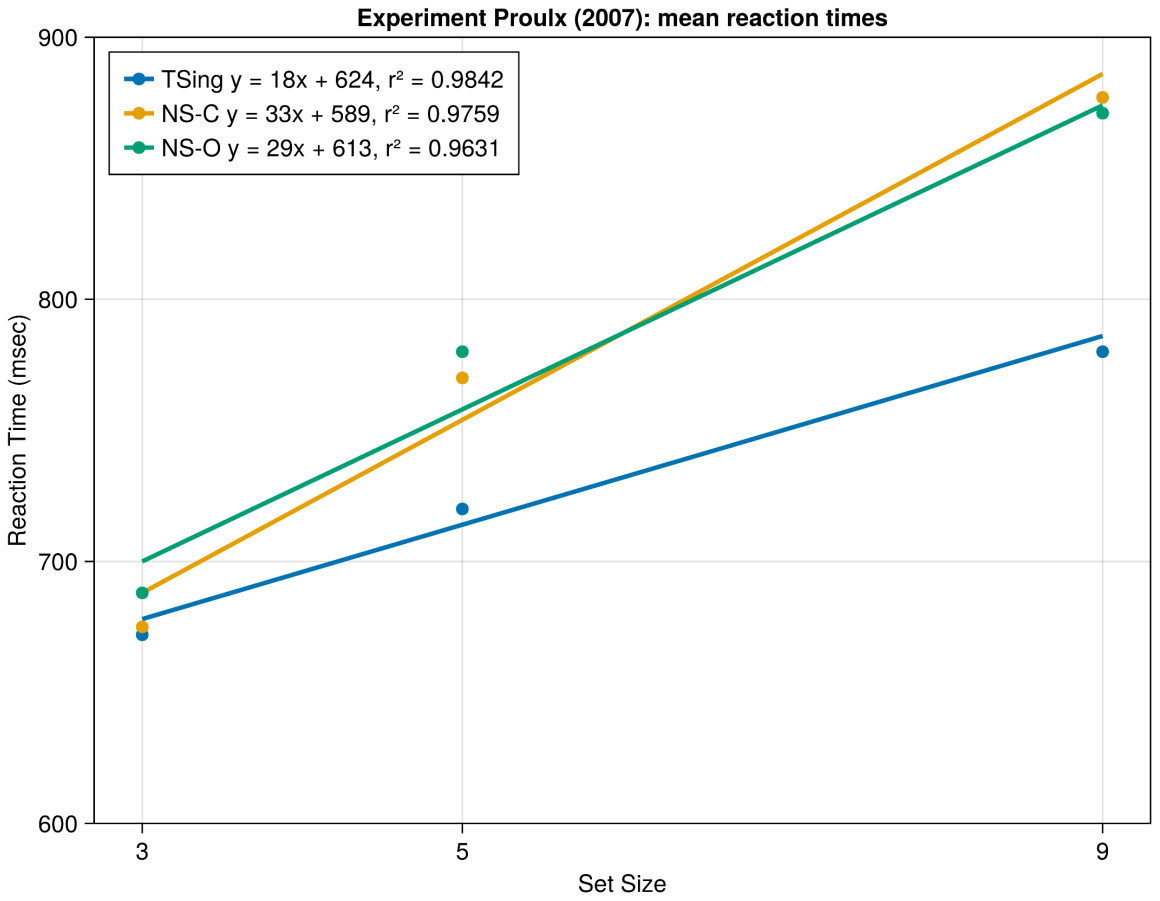
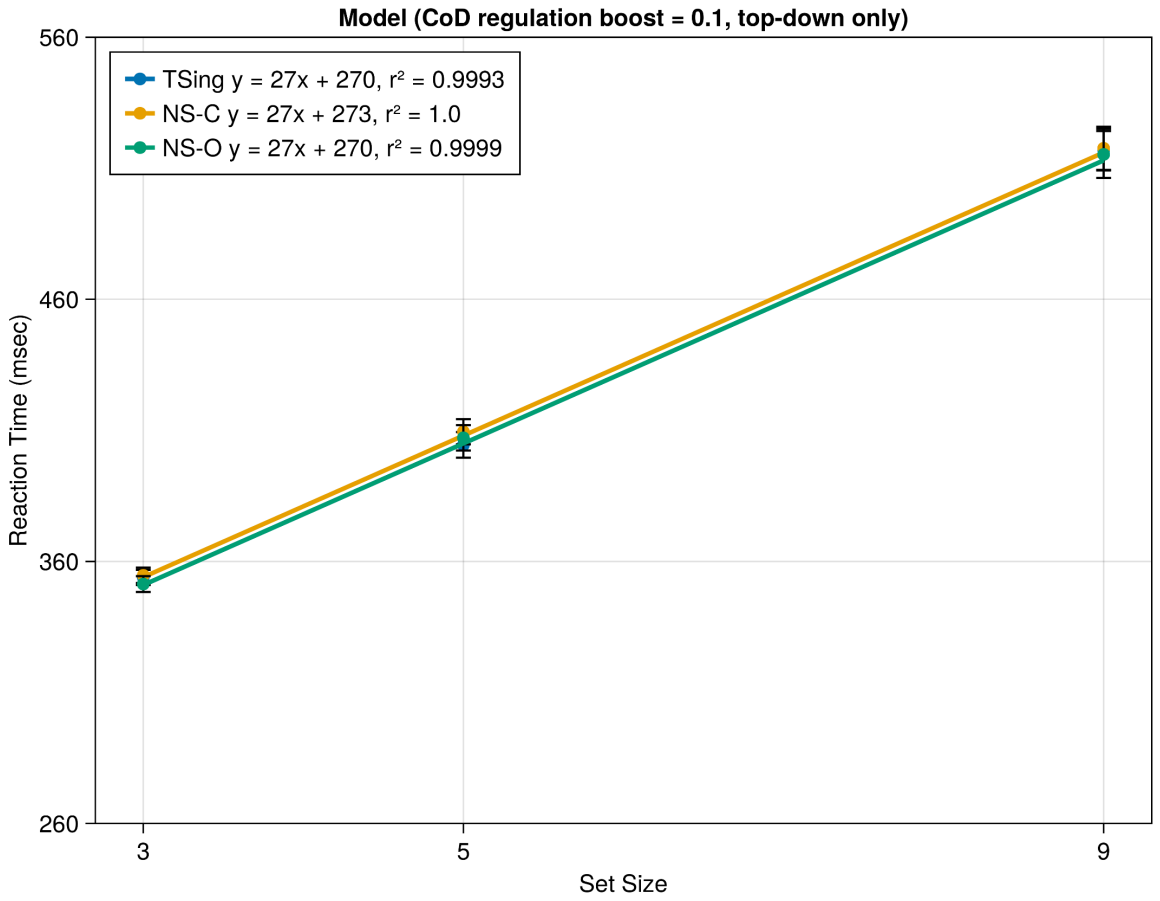
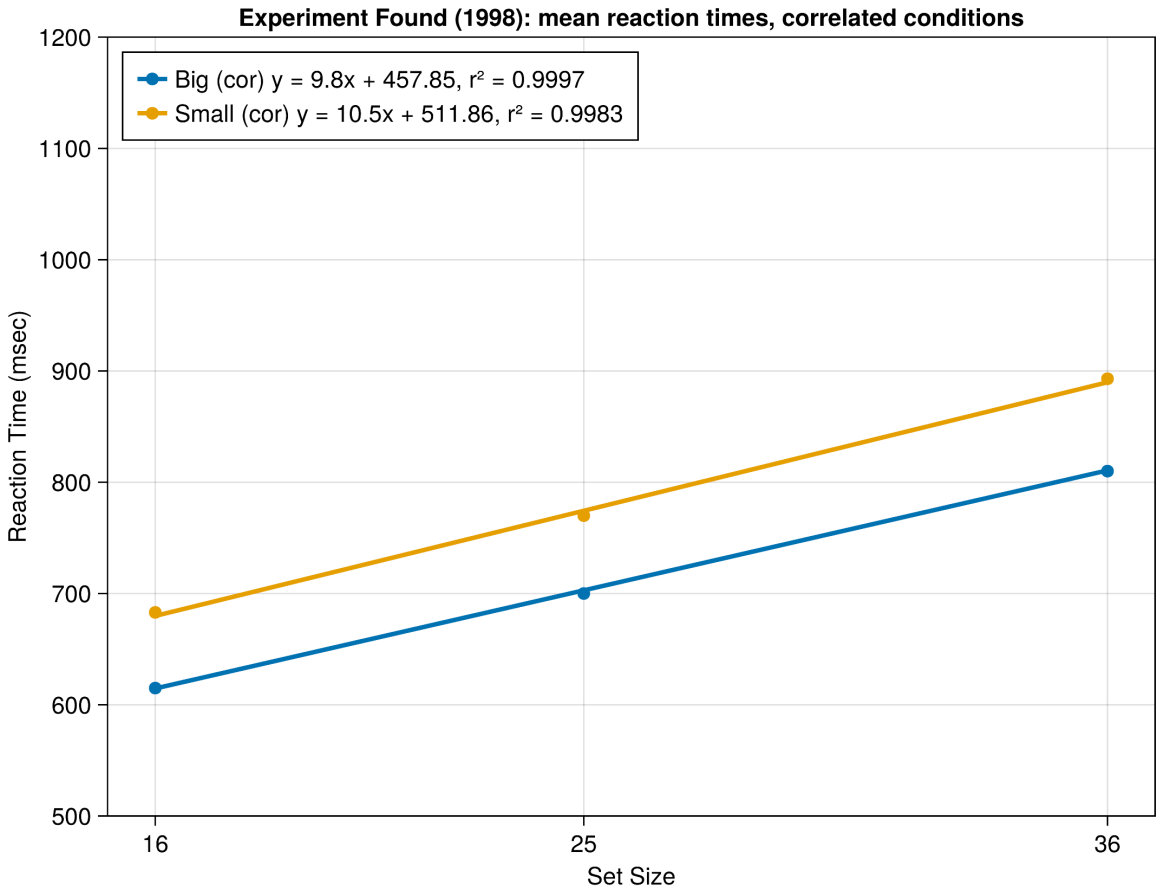
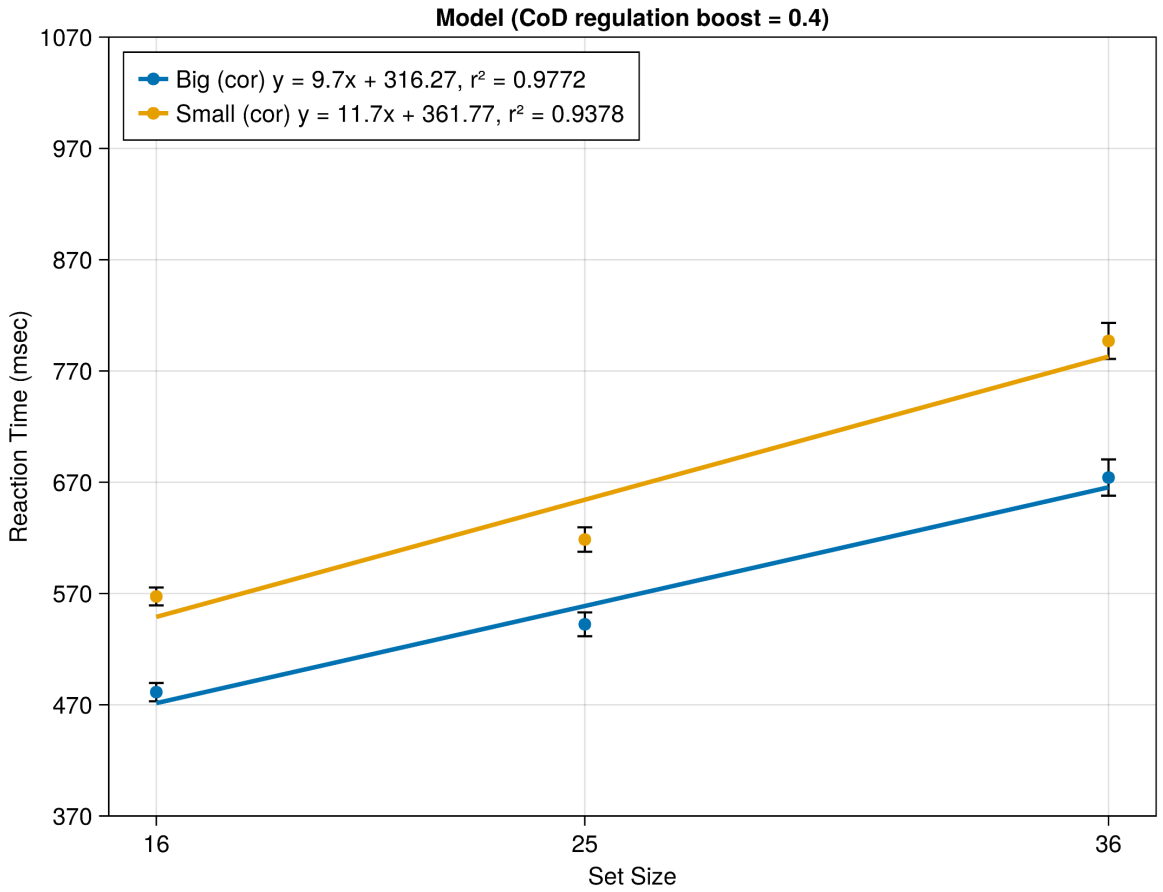




Model Results – Found (1998)





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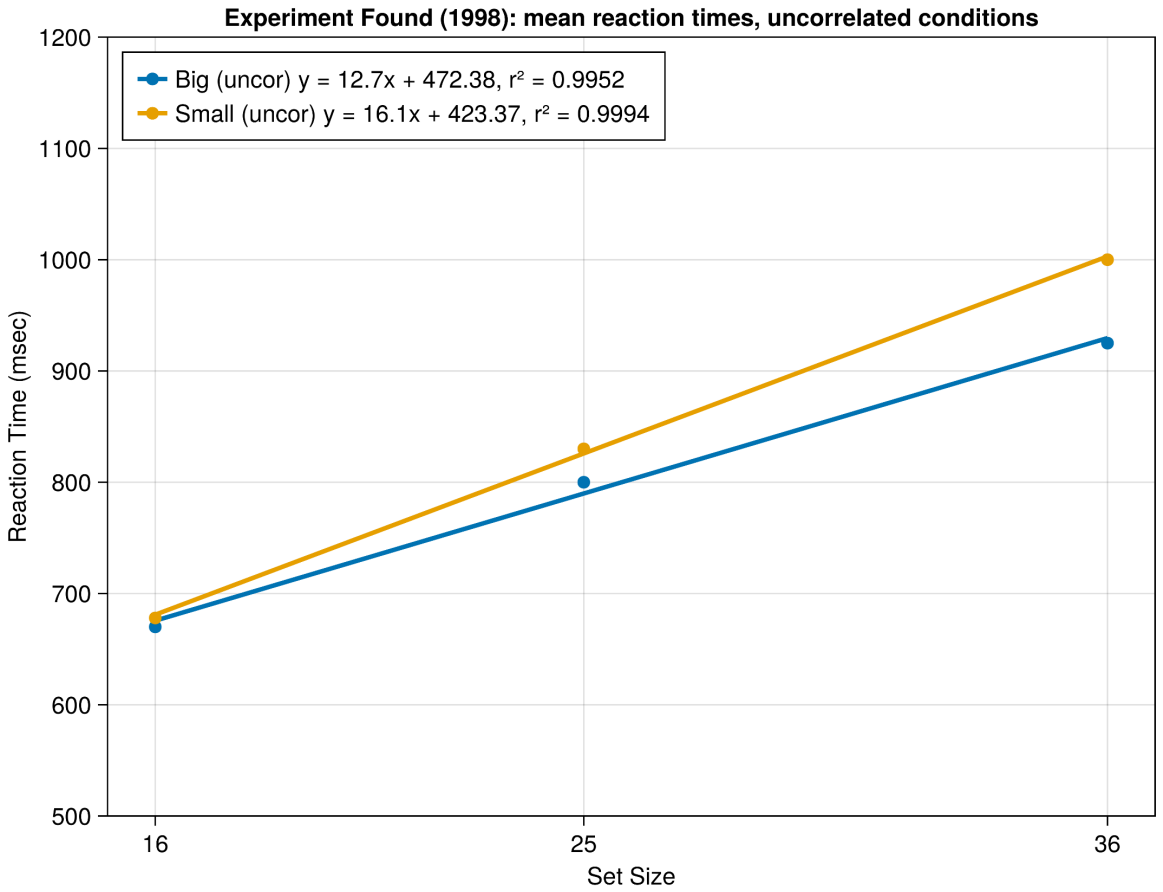

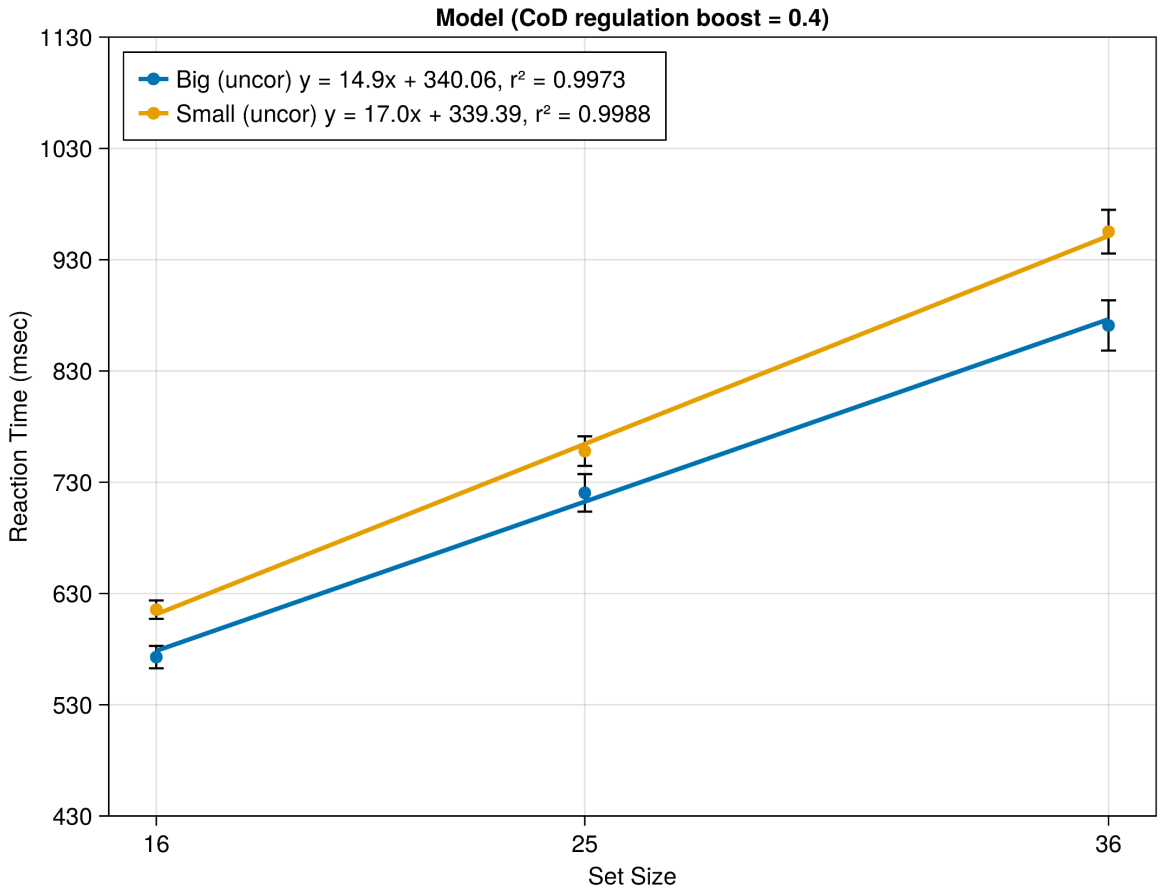

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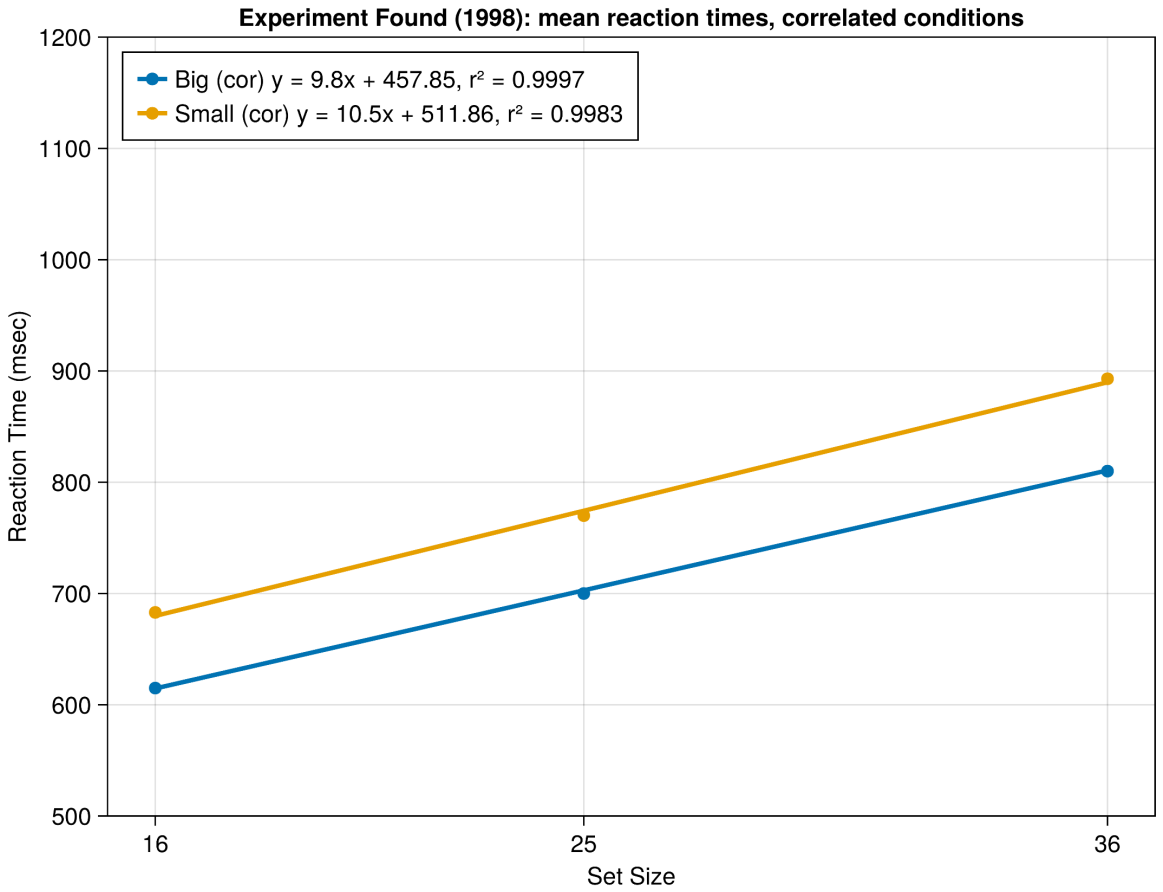

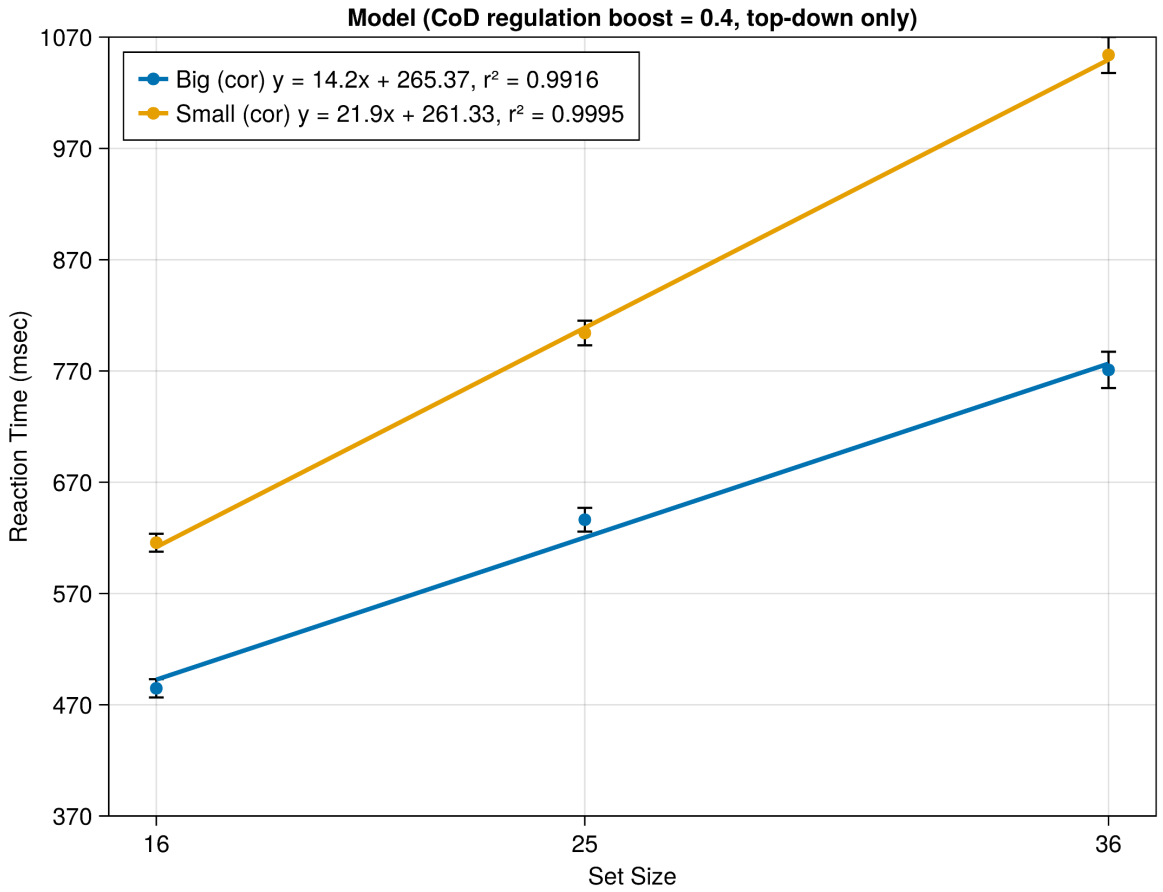

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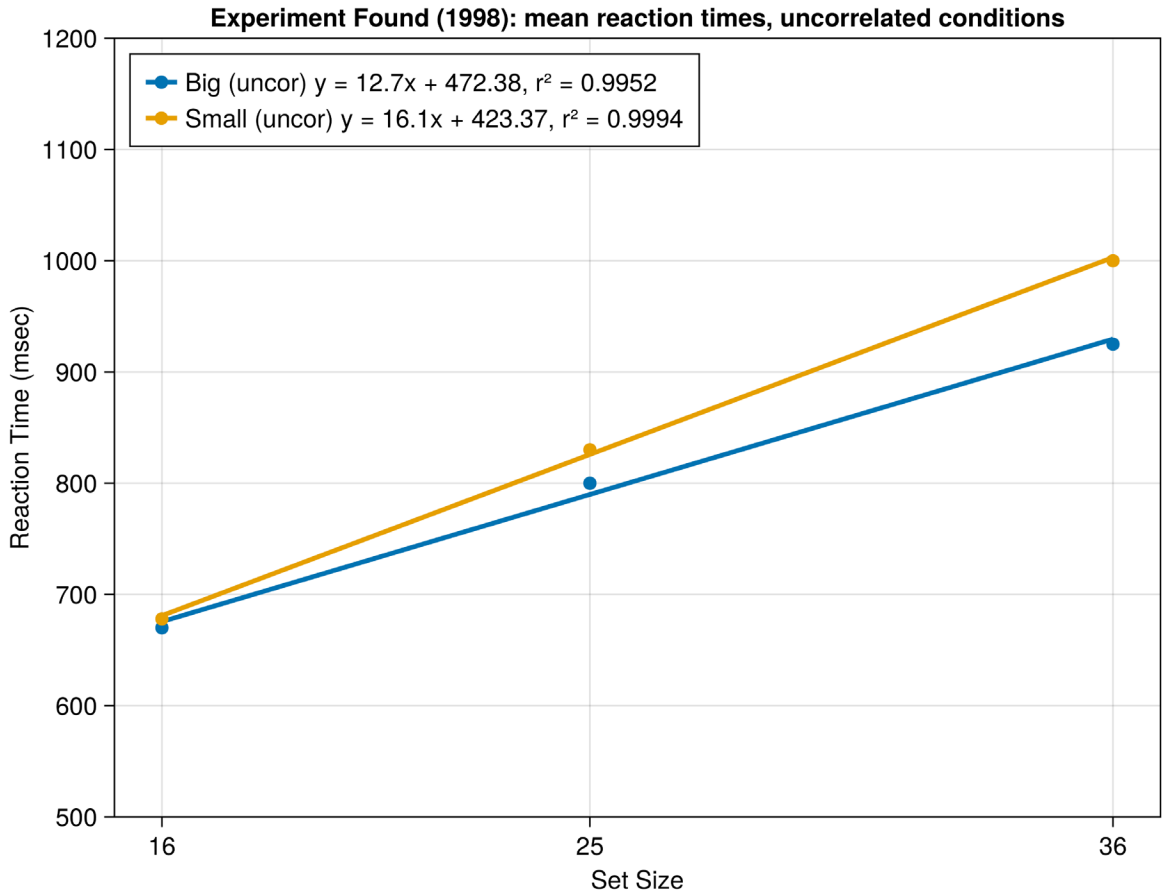
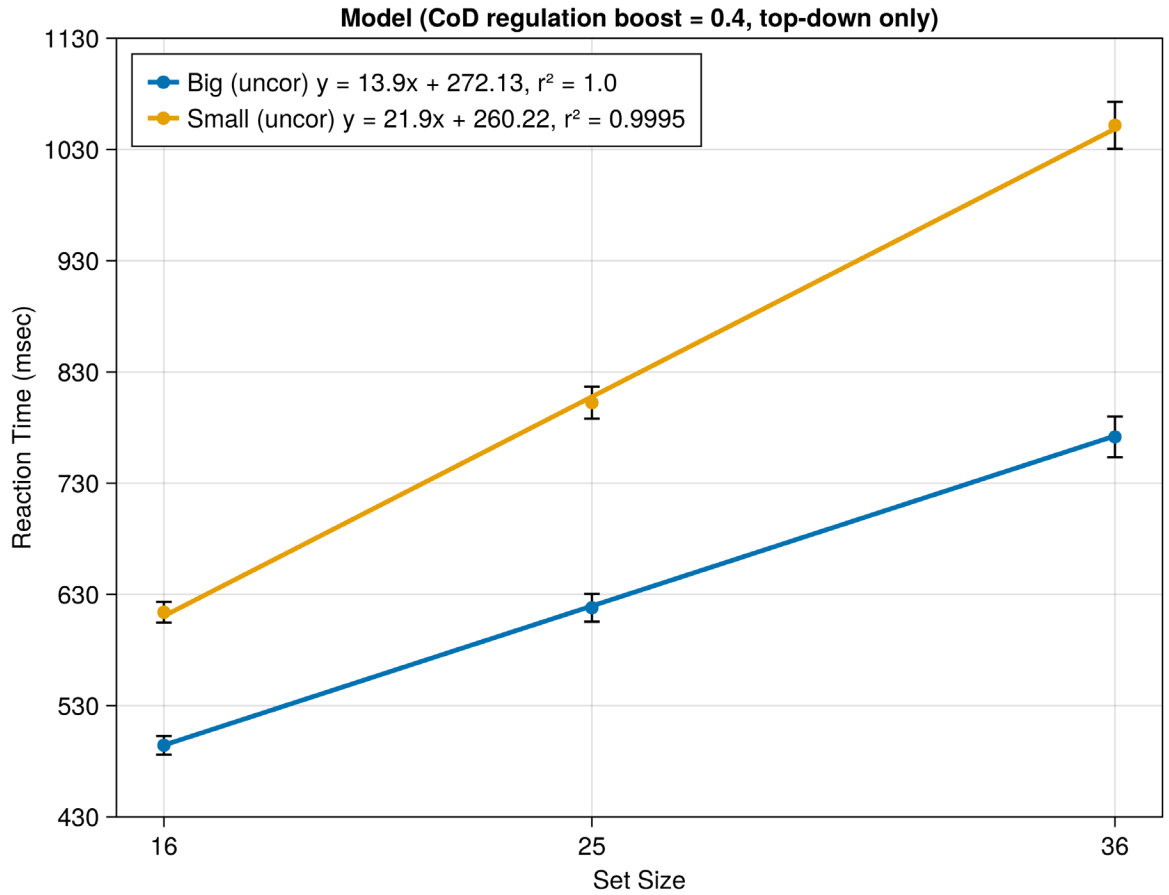
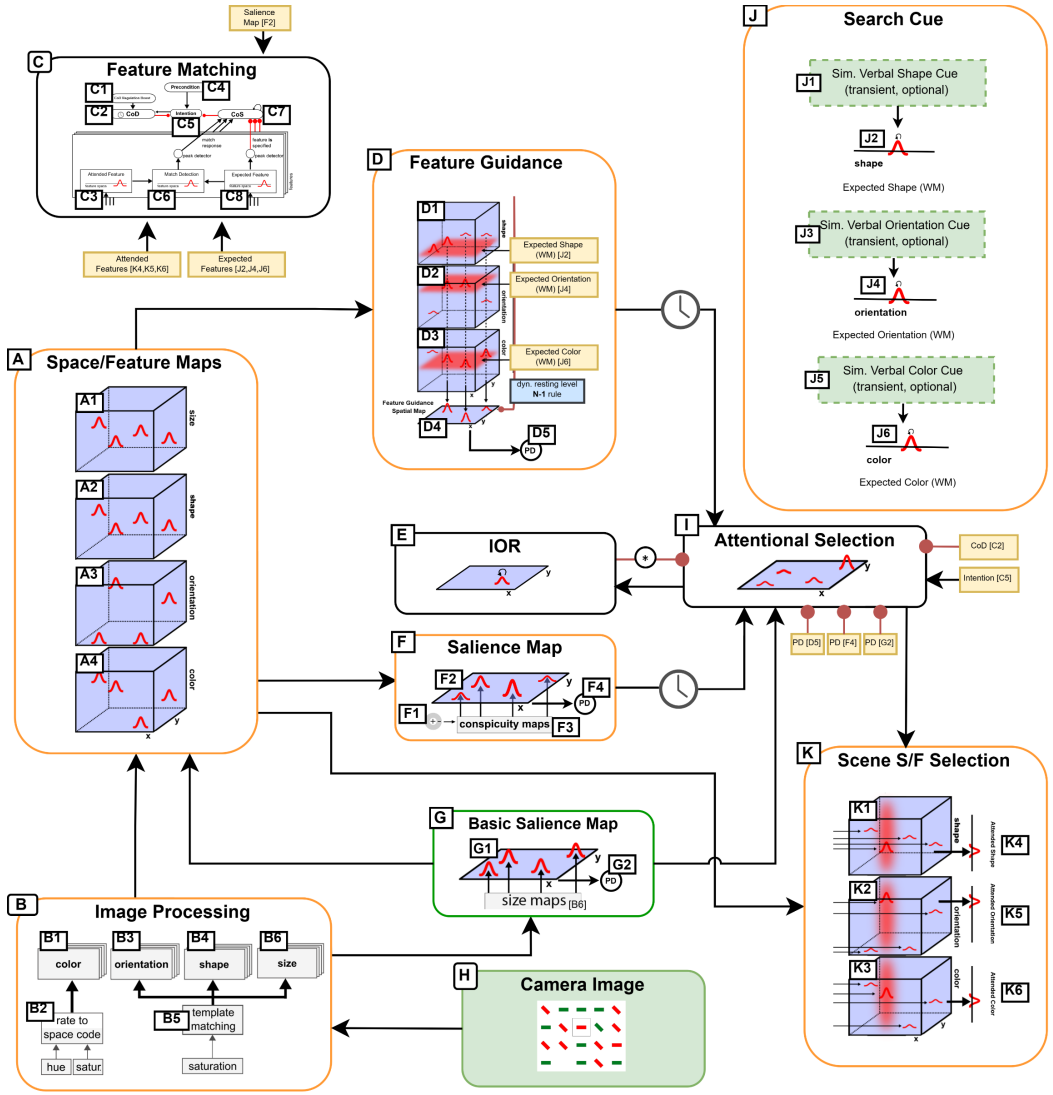




Model



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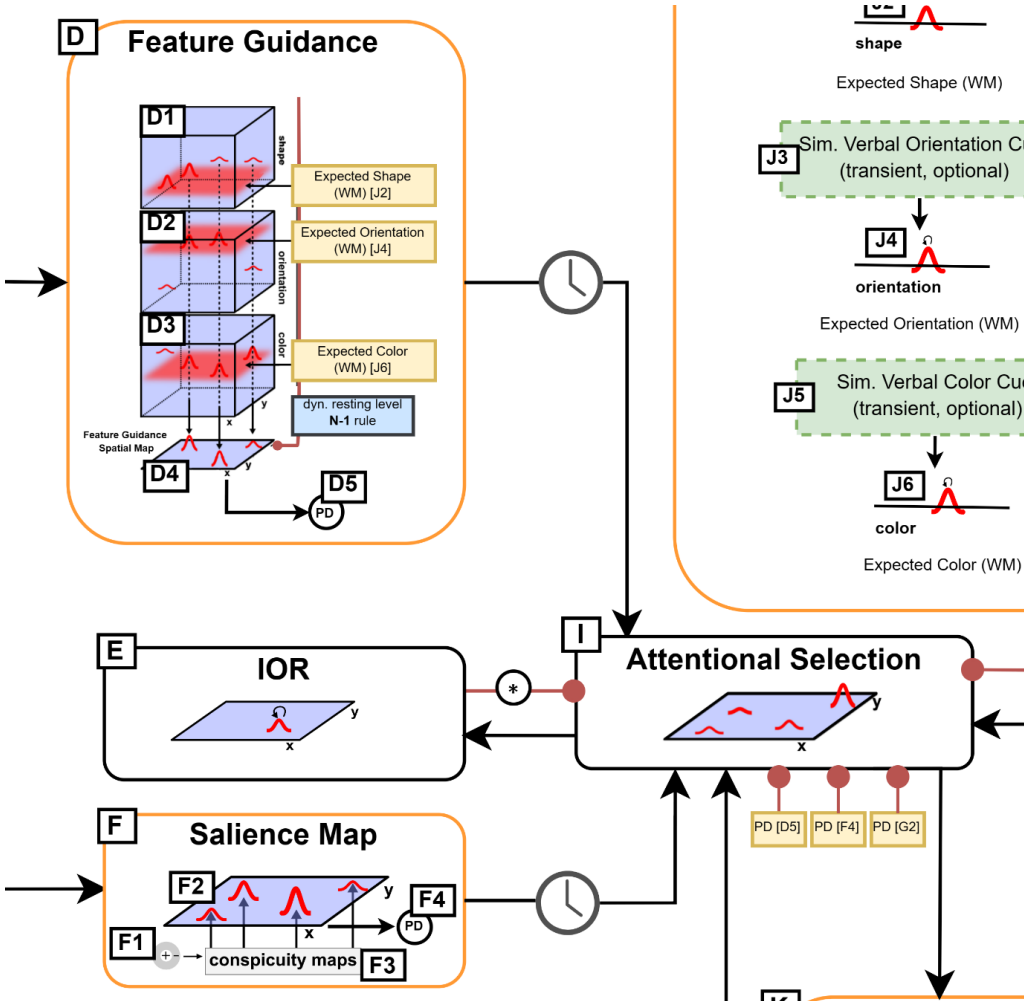
Model



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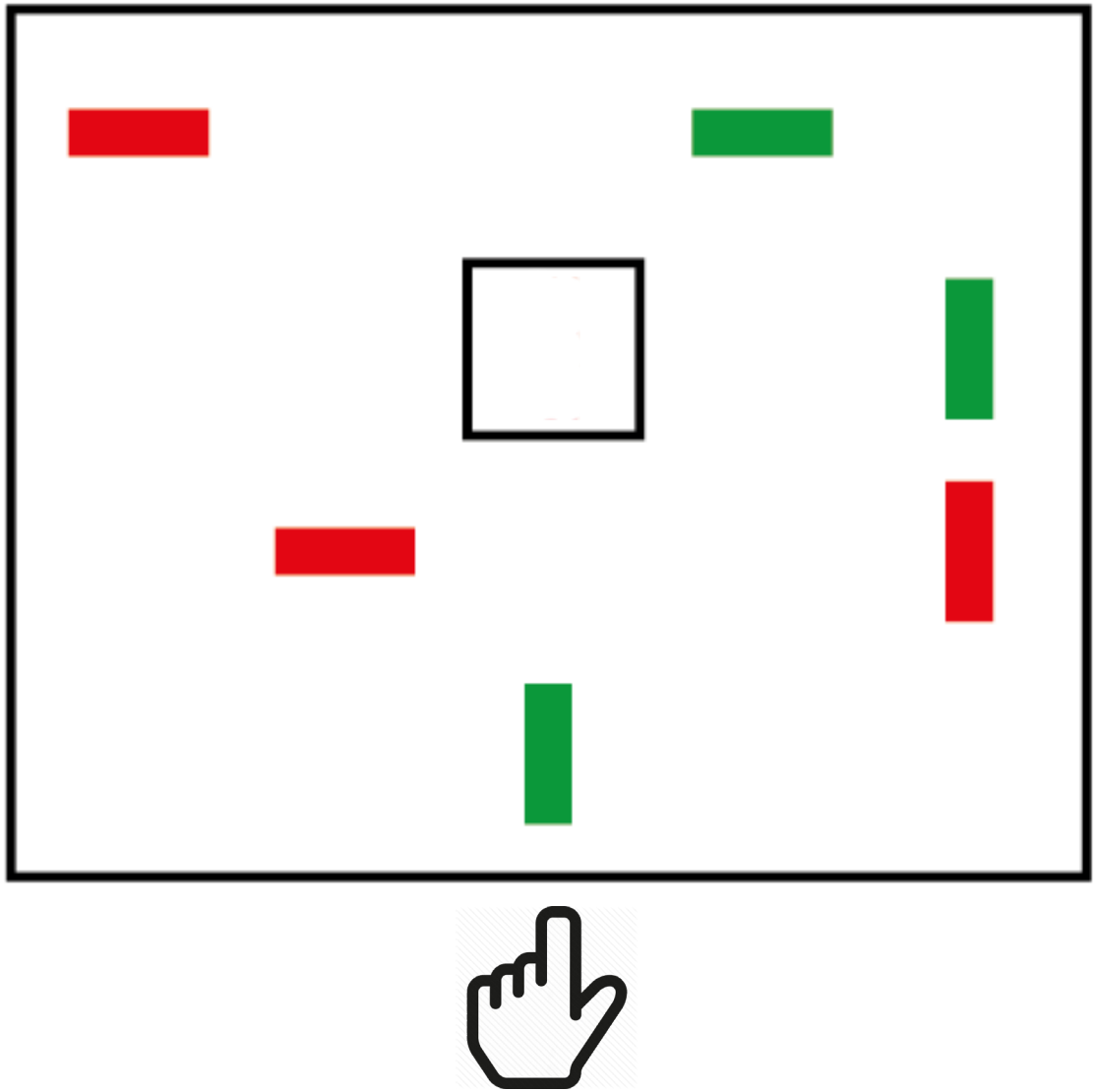
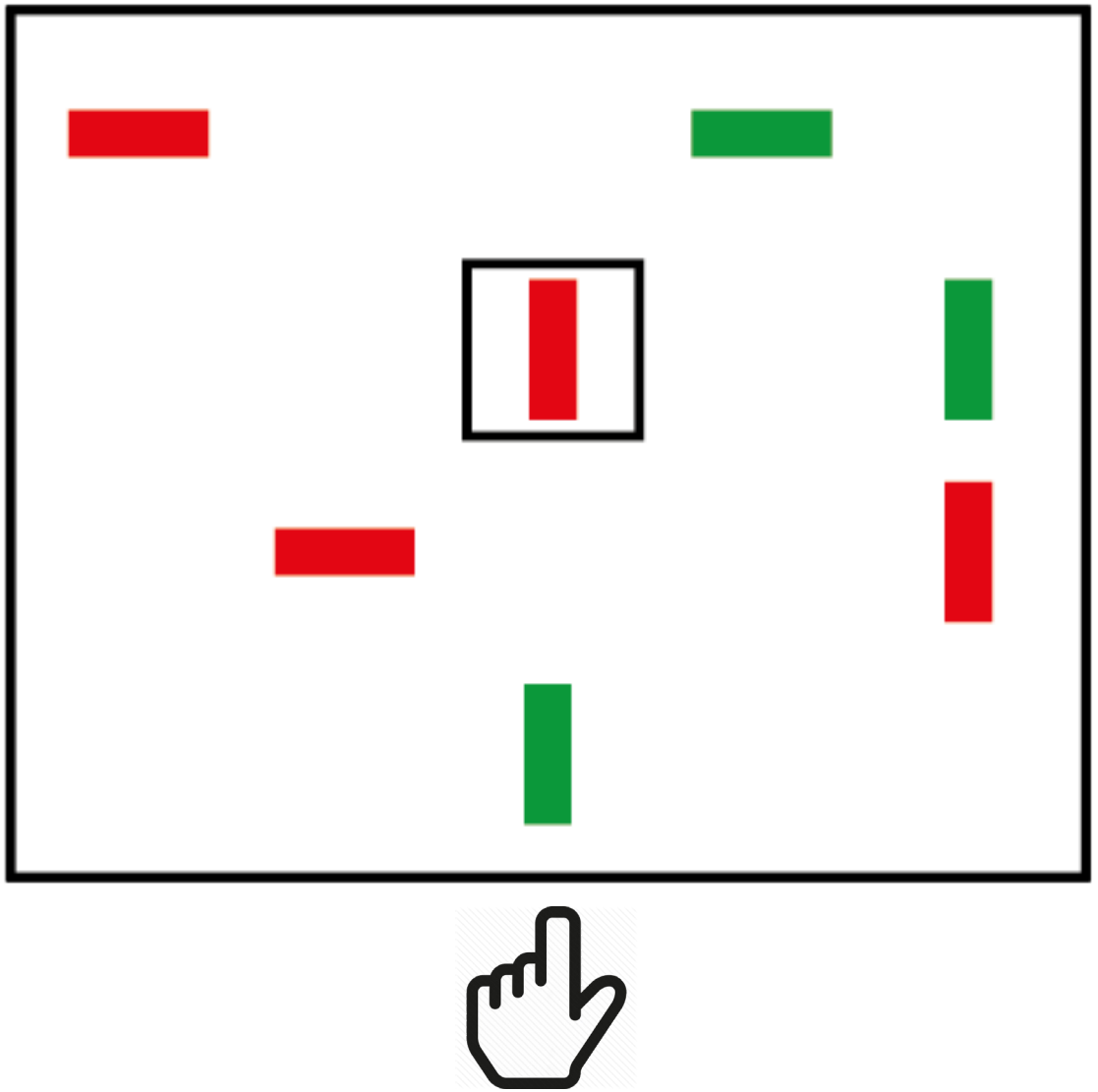
The Role of Memory in Visual Search

Scenario



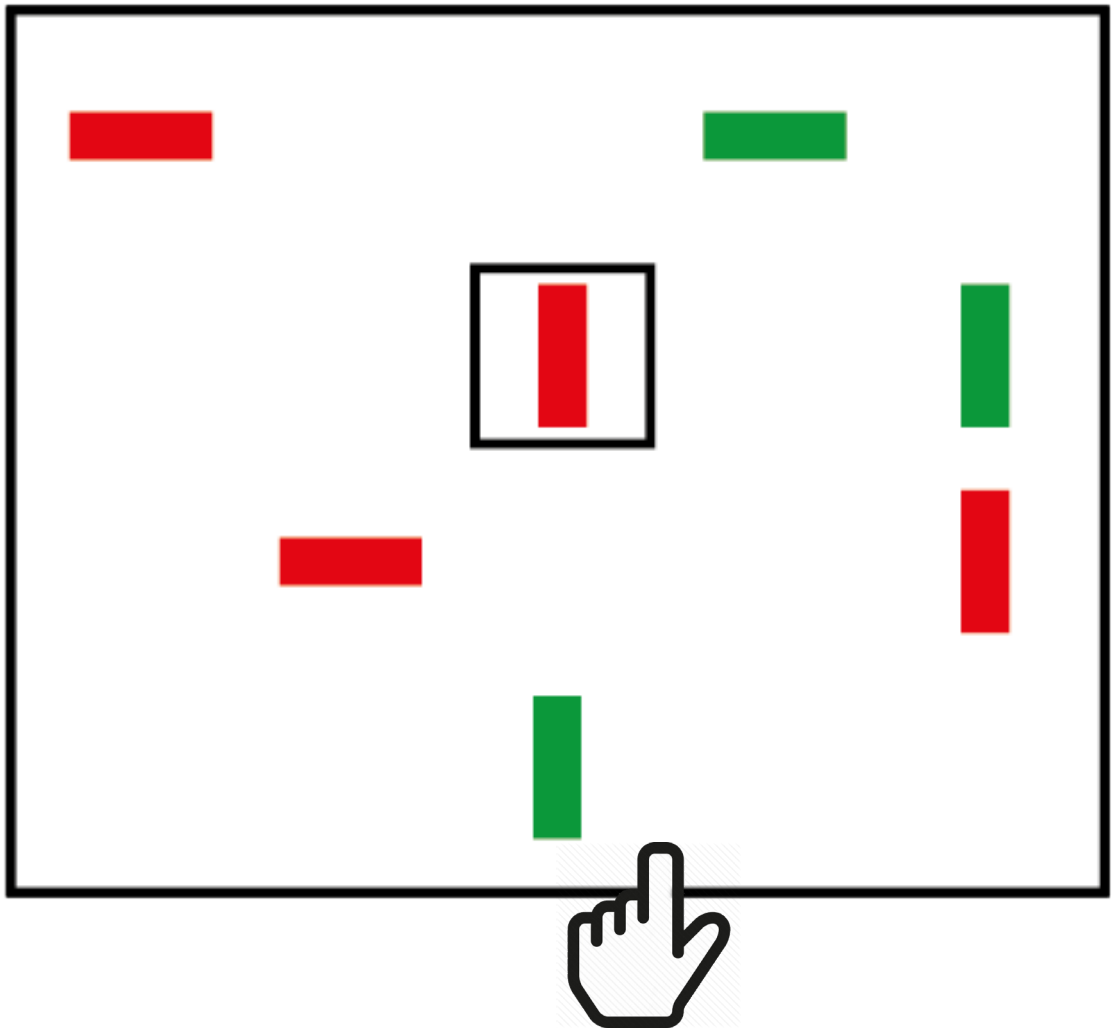
- Both **experiments** and **model** simulations are **based** on a **scenario**, in which participants **explore** a visual **scene**

Scenario



- Both experiments and model simulations are based on a scenario, in which participants explore a visual scene, are **cued** at some point to a visual **search task** by a sample **target** object that **appears** in the visual **array**

Scenario



- Both experiments and model simulations are based on a scenario, in which participants explore a visual scene, are cued at some point to a visual search task by a sample target object that appears in the visual array, and then **respond** by **indicating** the **location** of a **matching** visual **object**.

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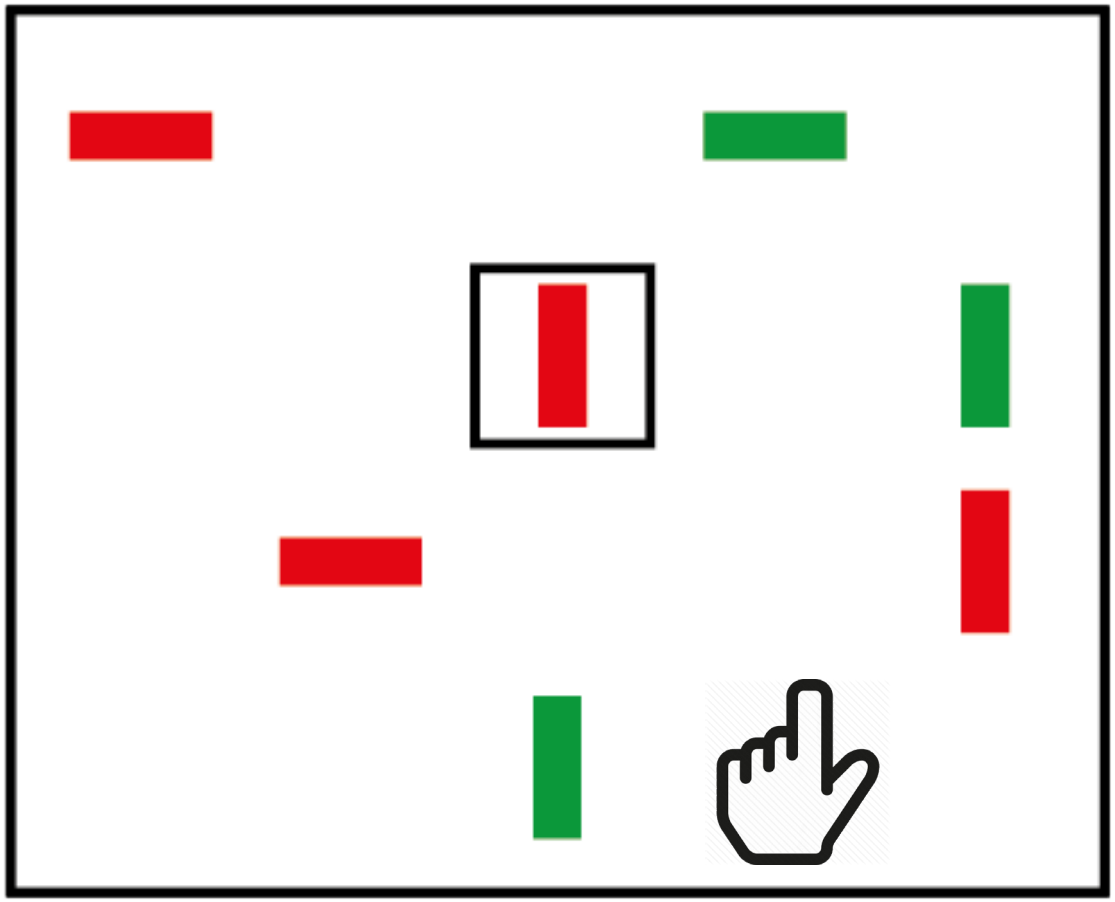

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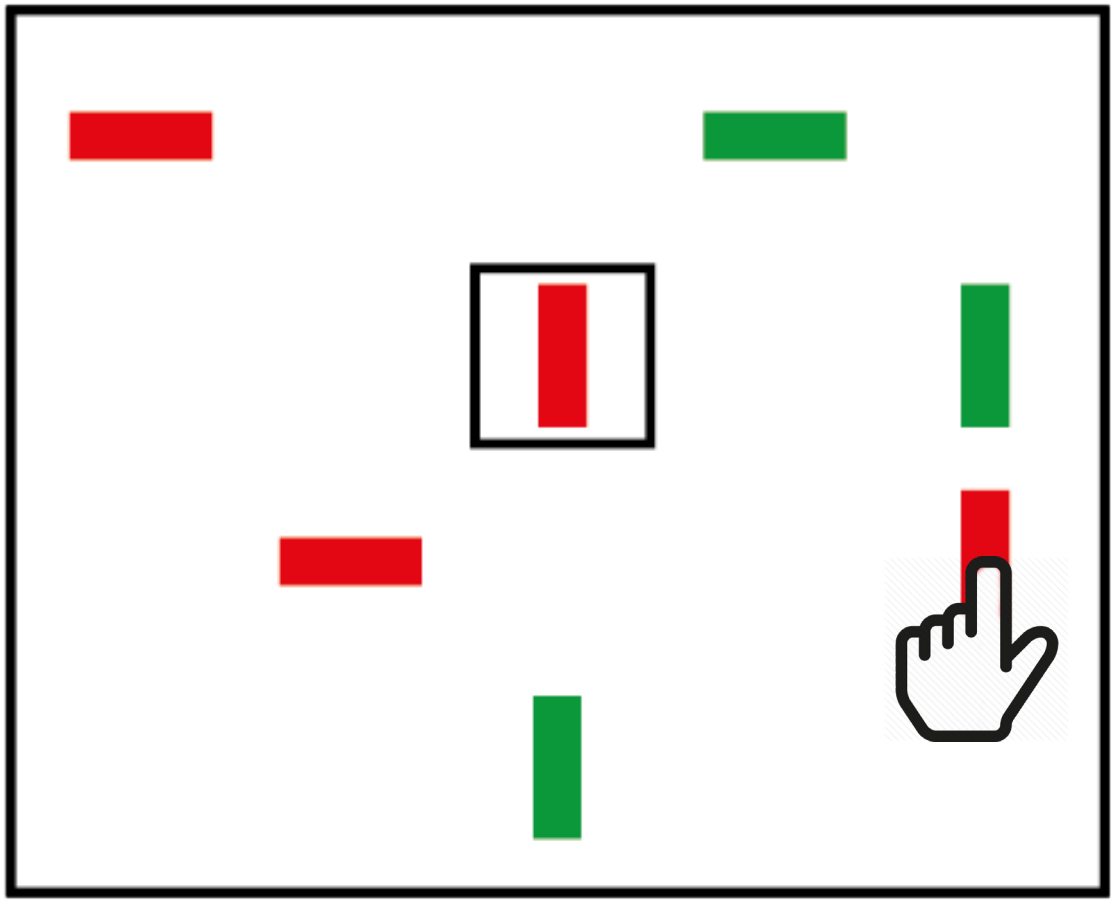

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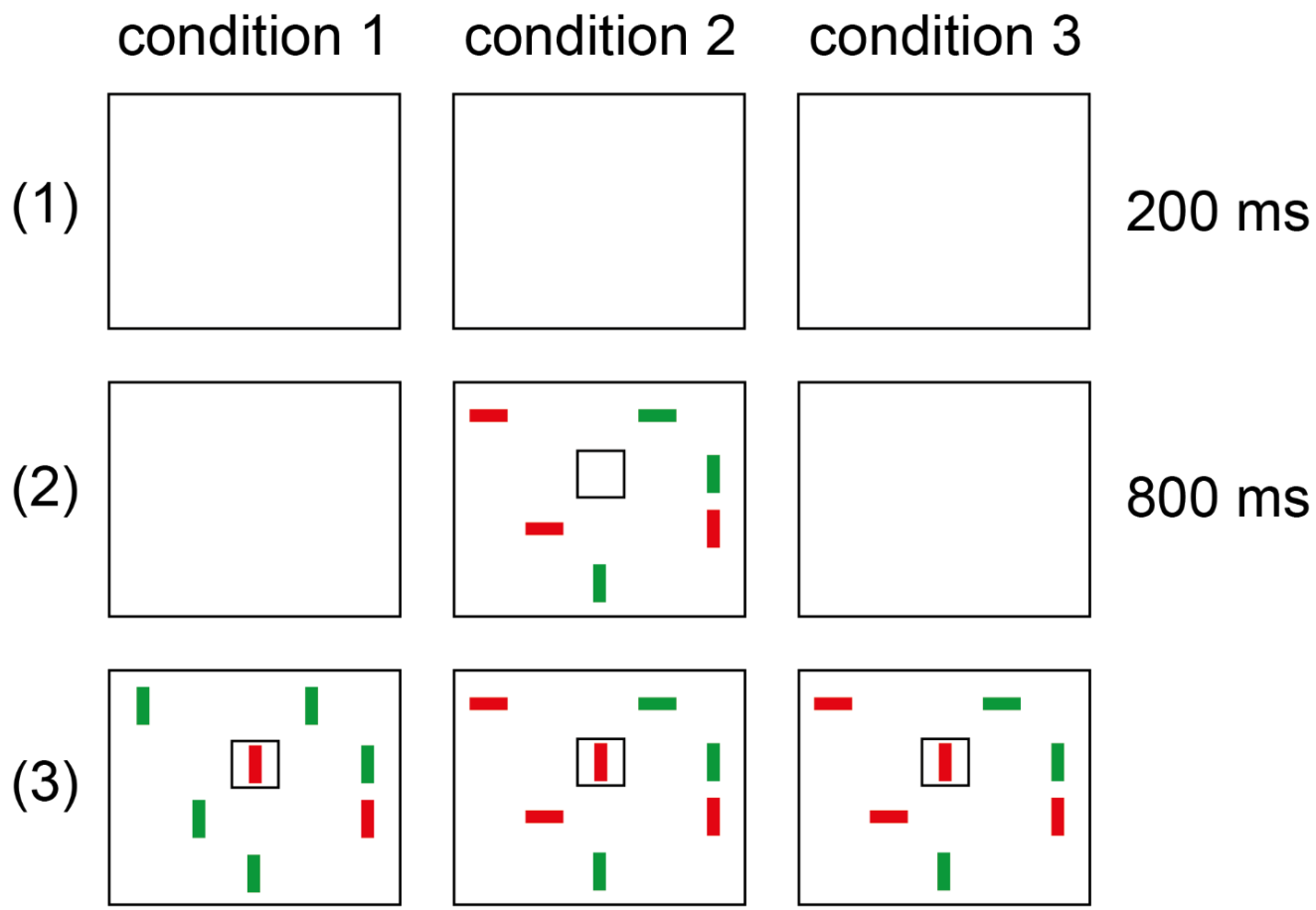
Experiment



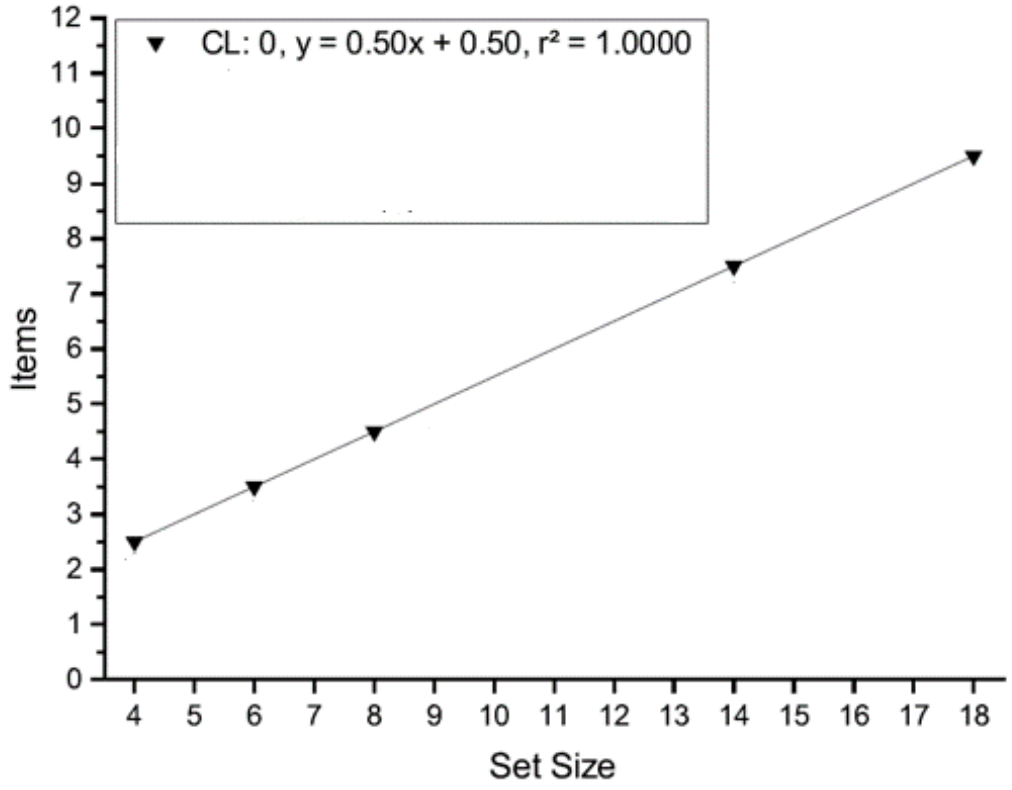
Grieben et al. Scene memory and spatial inhibition in visual search. Atten Percept Psychophys (2020)

Undisputed – the no memory case

- In a special case of inefficient conjunctive search it is well known that the average number of visited items is:

$$\frac{s+1}{2}$$

  - In this special case each item in the search array has the same selection probability
  - s is the *set size* (total number of items)
  - $s > 0$



Reason 1 – Target is in memory

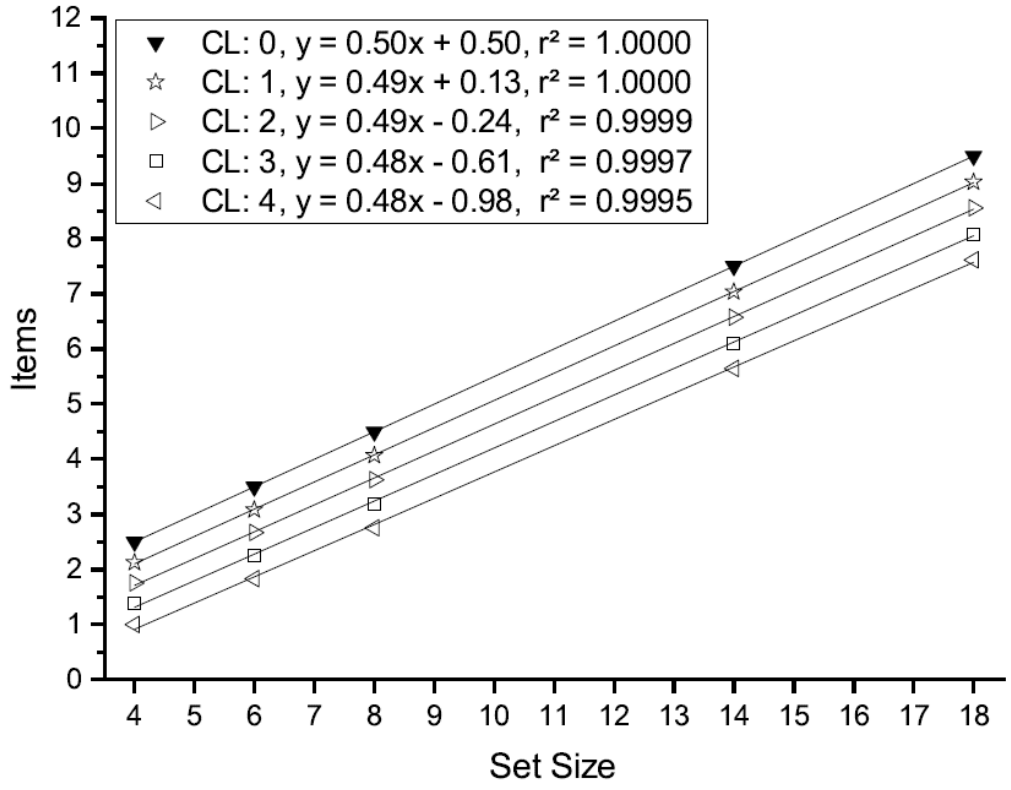
- The probability that the target is in memory:

$$p = \frac{CL}{s}$$

- CL is the *capacity limit* of working memory
- s is the *set size* (total number of items)
- $s > 0$
- The average number of visited items is now:

$$p + (1 - p)\frac{s + 1}{2}$$

- The **effect** on the **y-intercept** is **measurable**
- The **effect** on the **slope** is **negligible**



Reason 2 – Location of objects in memory are inhibited if target is not in memory

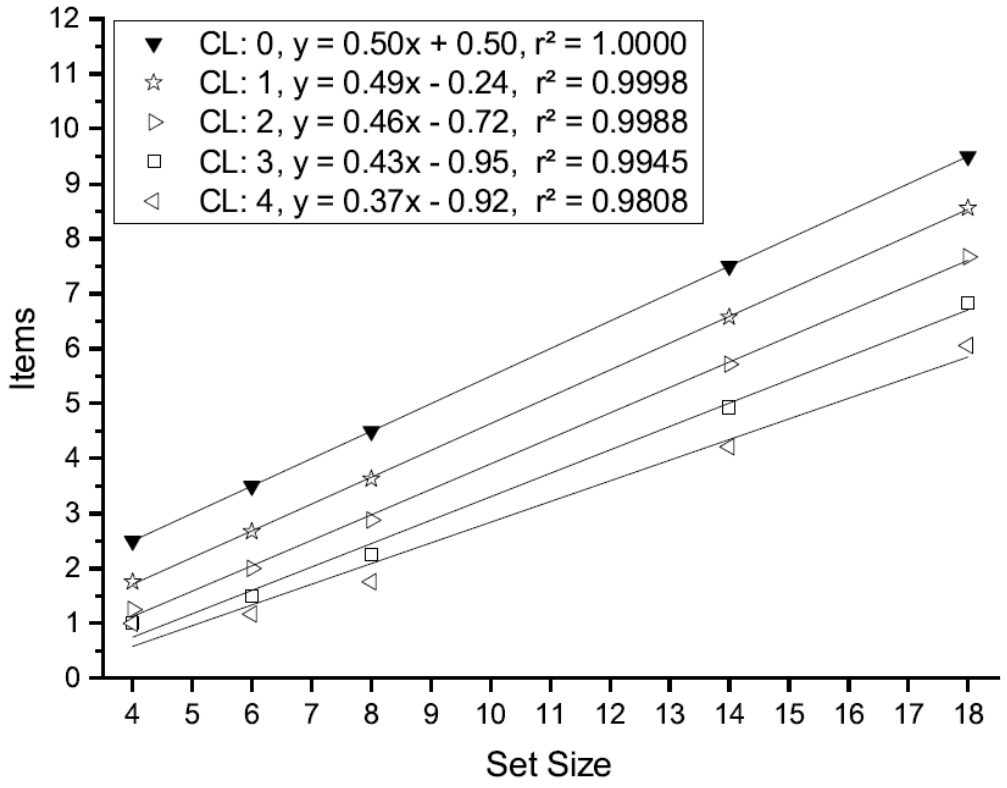
- The *set size* is now reduced by the *capacity limit*:

$$\frac{s - CL + 1}{2}$$

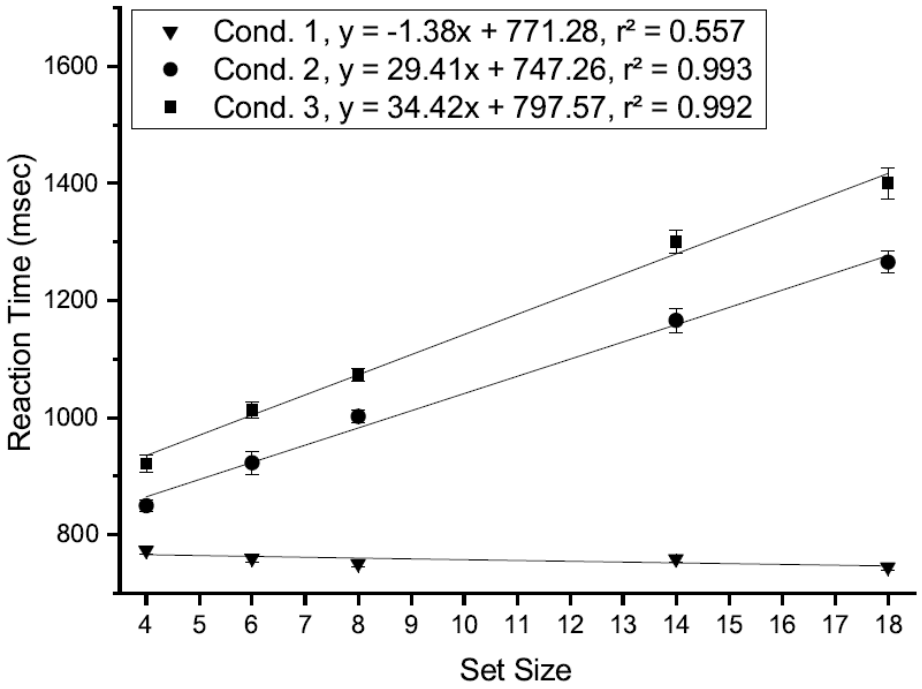
- CL is the *capacity limit* of working memory
- s is the *set size* (total number of items)
- $s > 0$
- The average number of visited items is now:

$$p + (1 - p)\frac{s - CL + 1}{2}$$

- The **effect** on the **y-intercept** is **measurable**
- The **effect** on the **slope** is **measurable**



Experiment 1 - RT



- 19 participants
- the search slope in condition 3 was significantly steeper than in condition 2
  (t(17)=2.639; p=.017; d=.593)

- Calculated ratio for CL=3 was:

$$\frac{0.4256}{0.5} = 0.8512$$

- Ratio from experimental data is:

$$\frac{29.40653}{34.42764} = 0.8542$$

- **This is the first experimental observation of the combined effect of guidance (Reason 1) and inhibition (Reason 2) from working memory in this kind of task**

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Experiment 2

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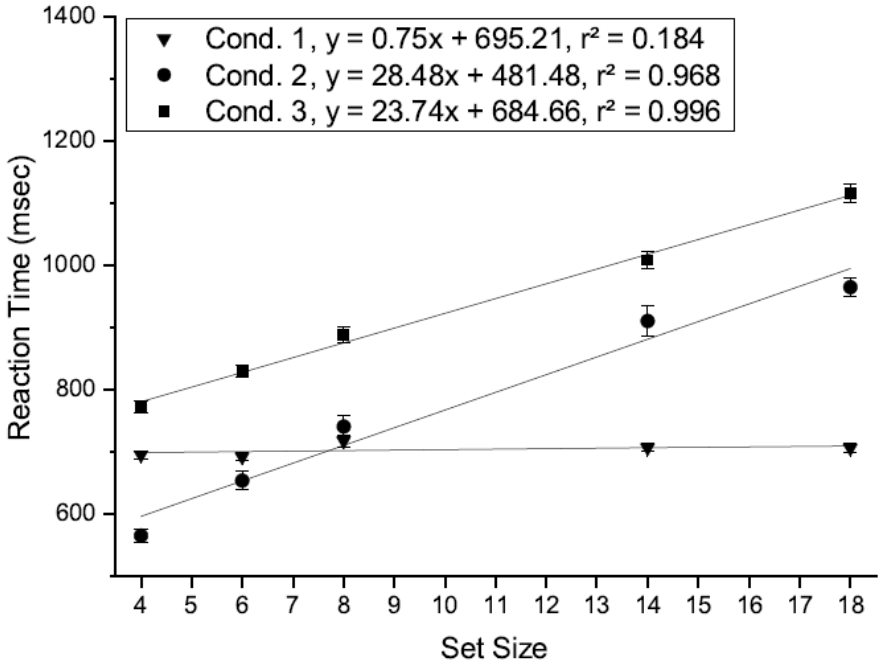
Experiment 2 - RT



- The lower set sizes (4, 6, 8) of condition 2 showed the typical signature of an in-memory search.
- So we analyzed slopes separately for the three lowest set sizes (4, 6, 8) and the higher set sizes (8, 14, 18).

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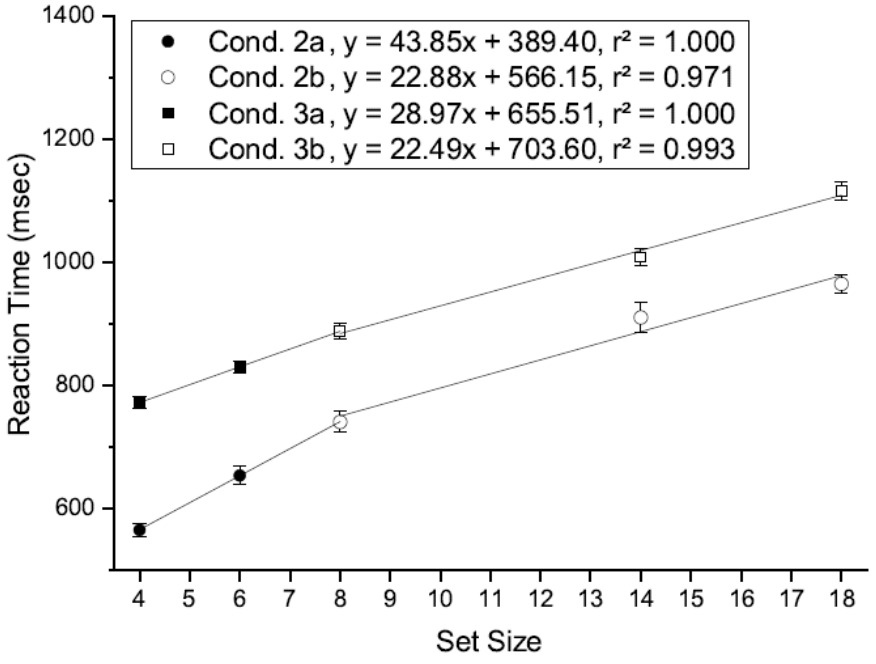
Experiment 2 - RT



- Experiment 2 showed that the inhibitory effect of working memory on the efficiency of visual search can easily be disrupted, without interfering with the content and guidance from working memory.
  => **same slope, different y-intercept**
- Supporting the notion that inhibition comes from a separate memory subsystem.
- Experiment 2 also suggested that this separate (spatial) memory subsystem is less stable than scene memory.

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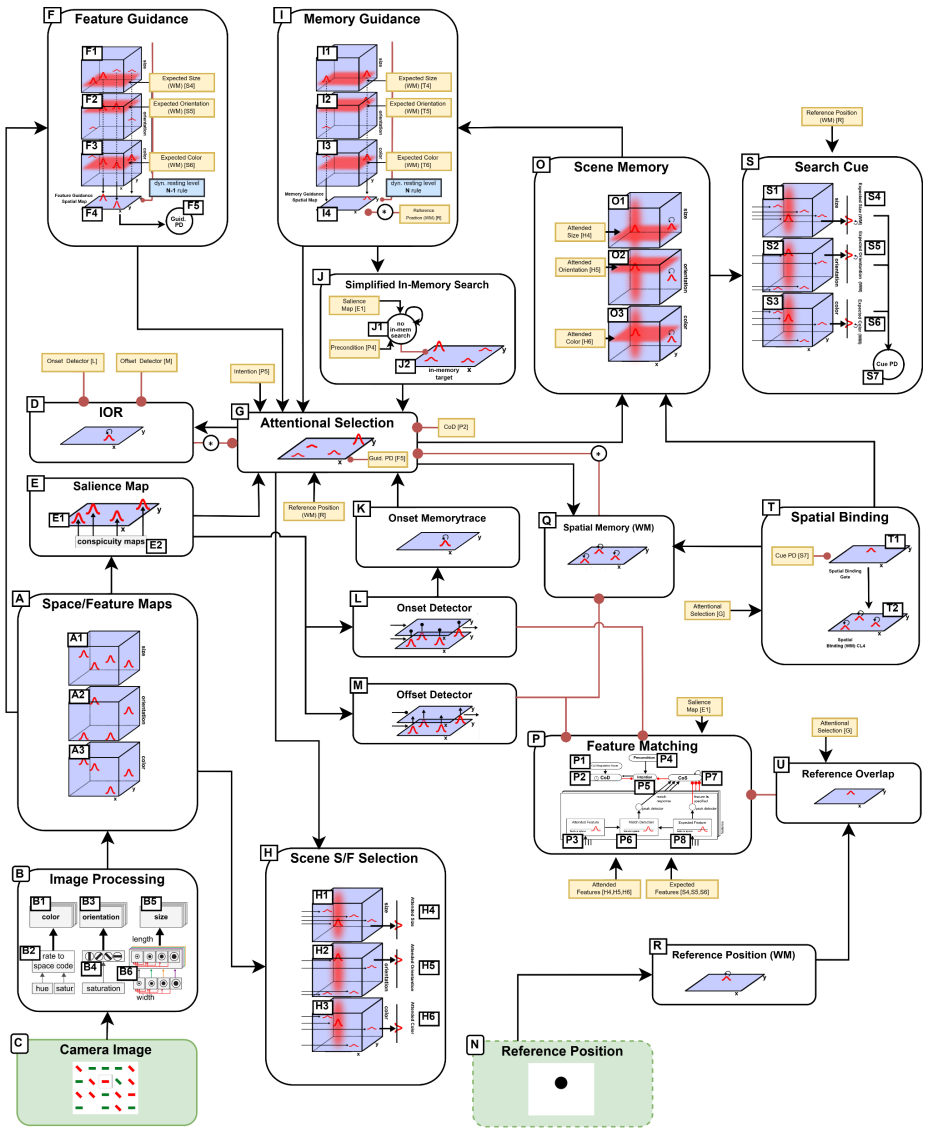
Model



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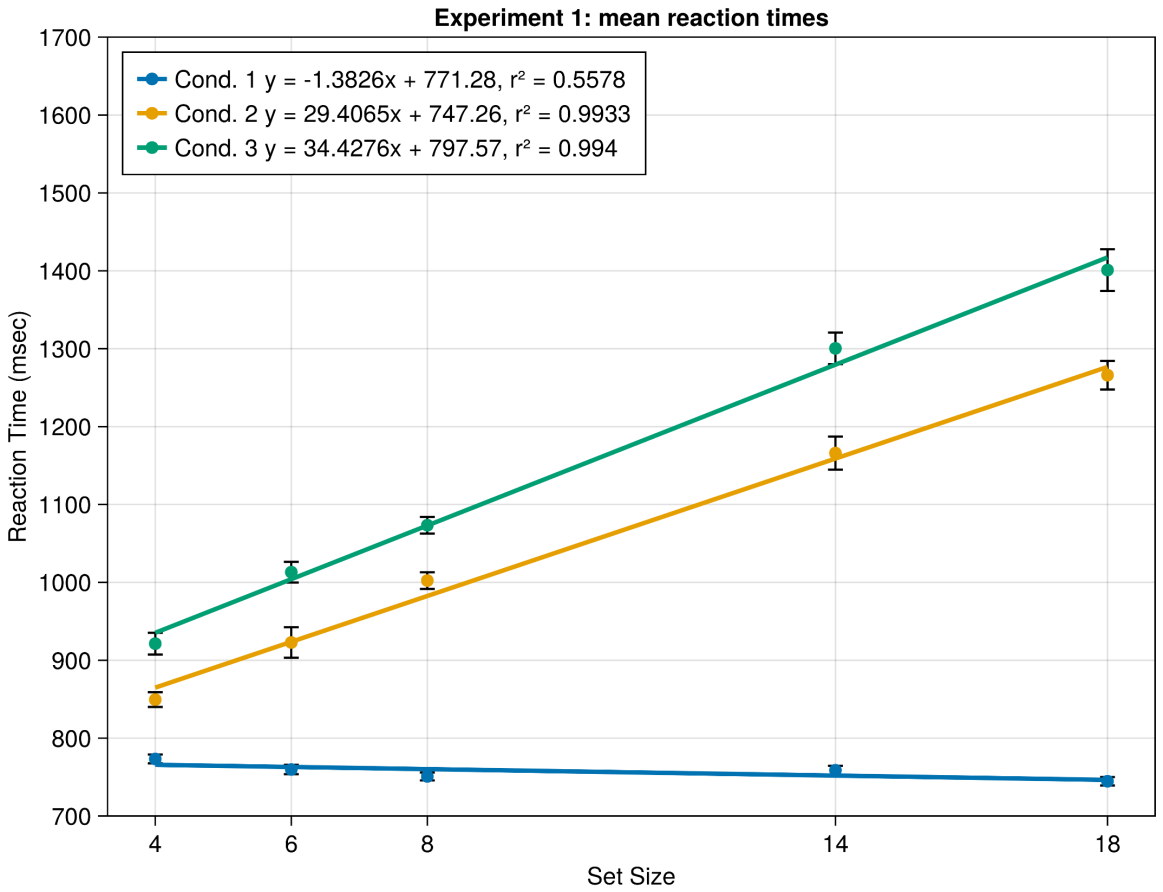
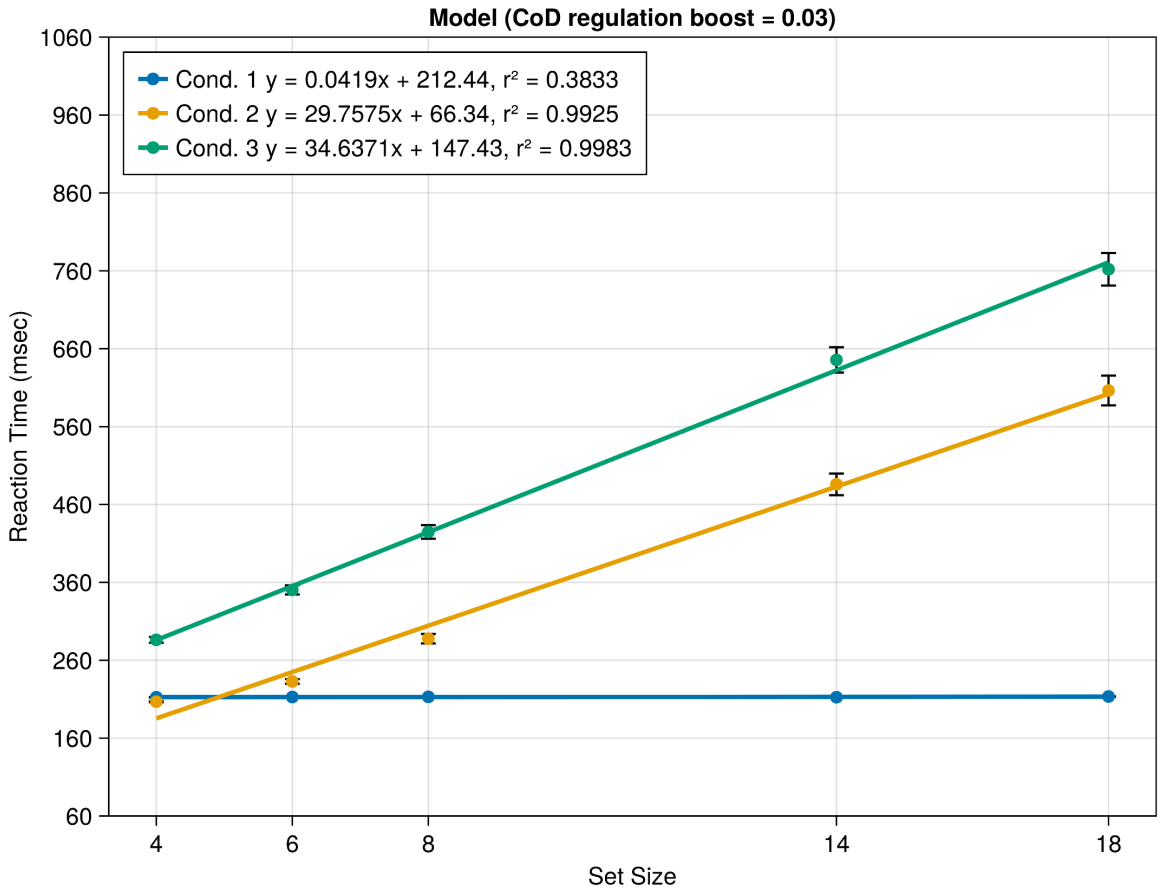
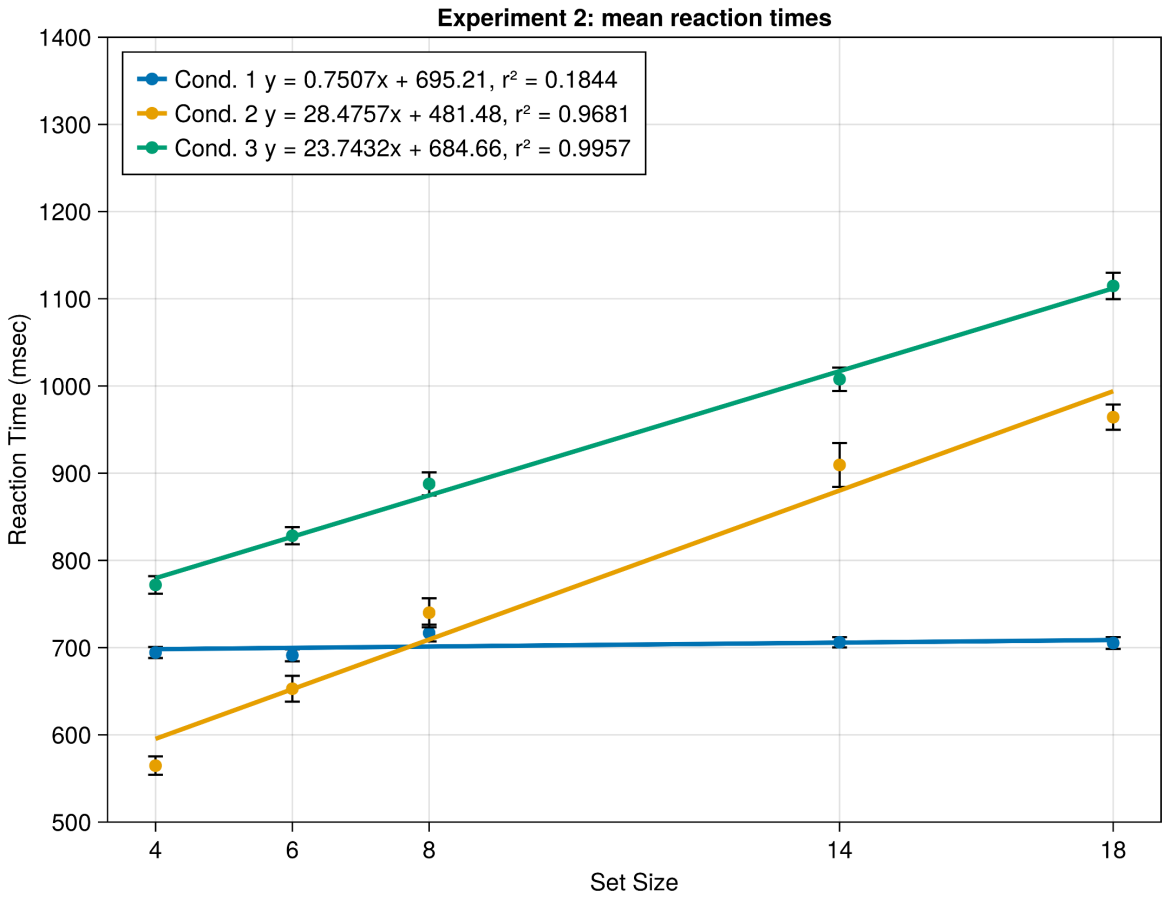
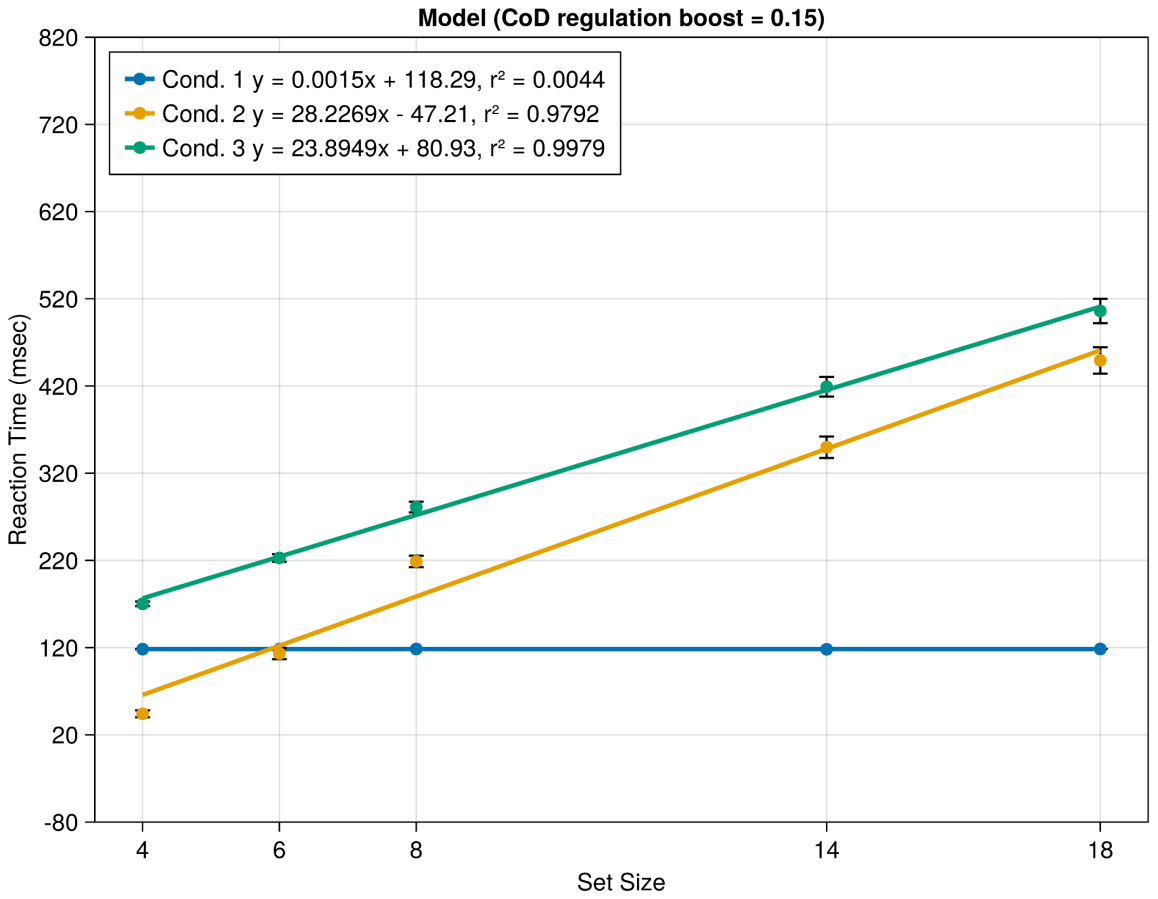
Model Results – Experiment 1



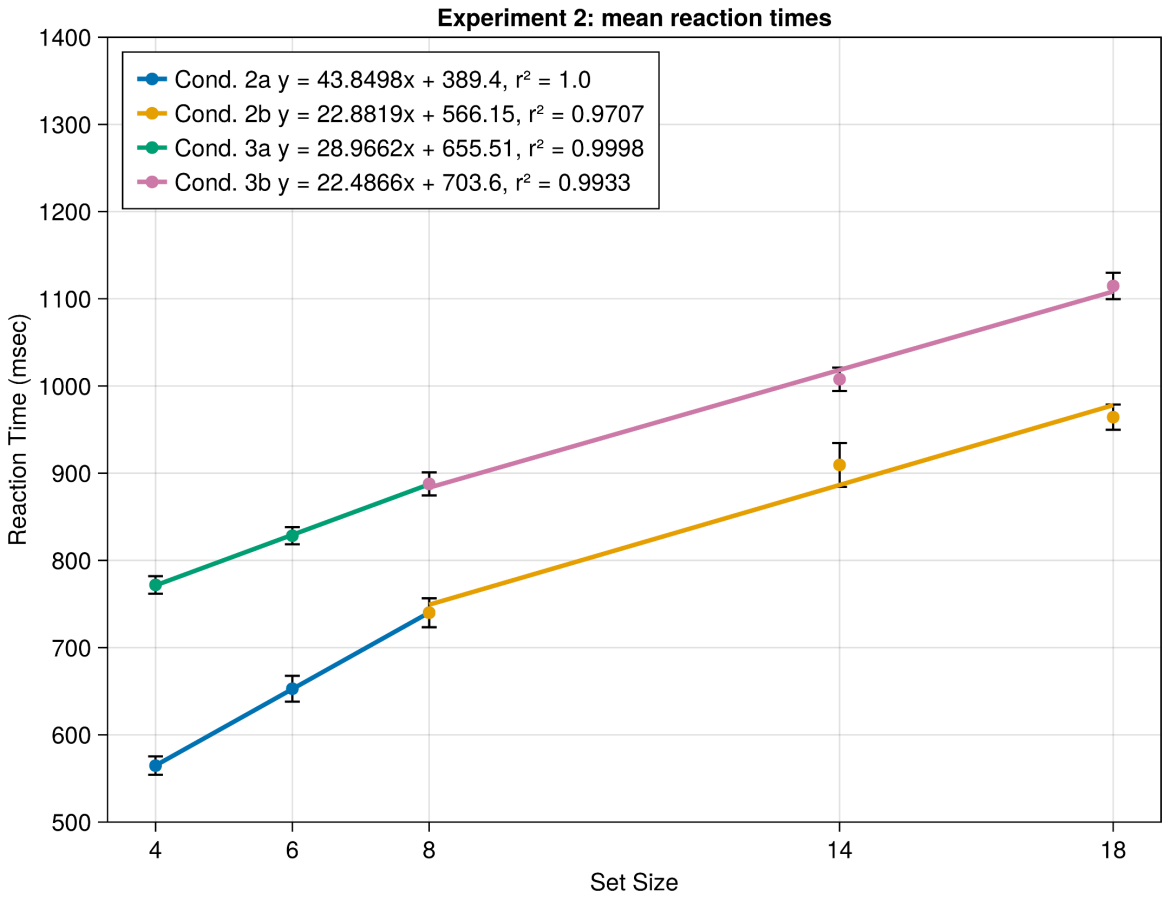


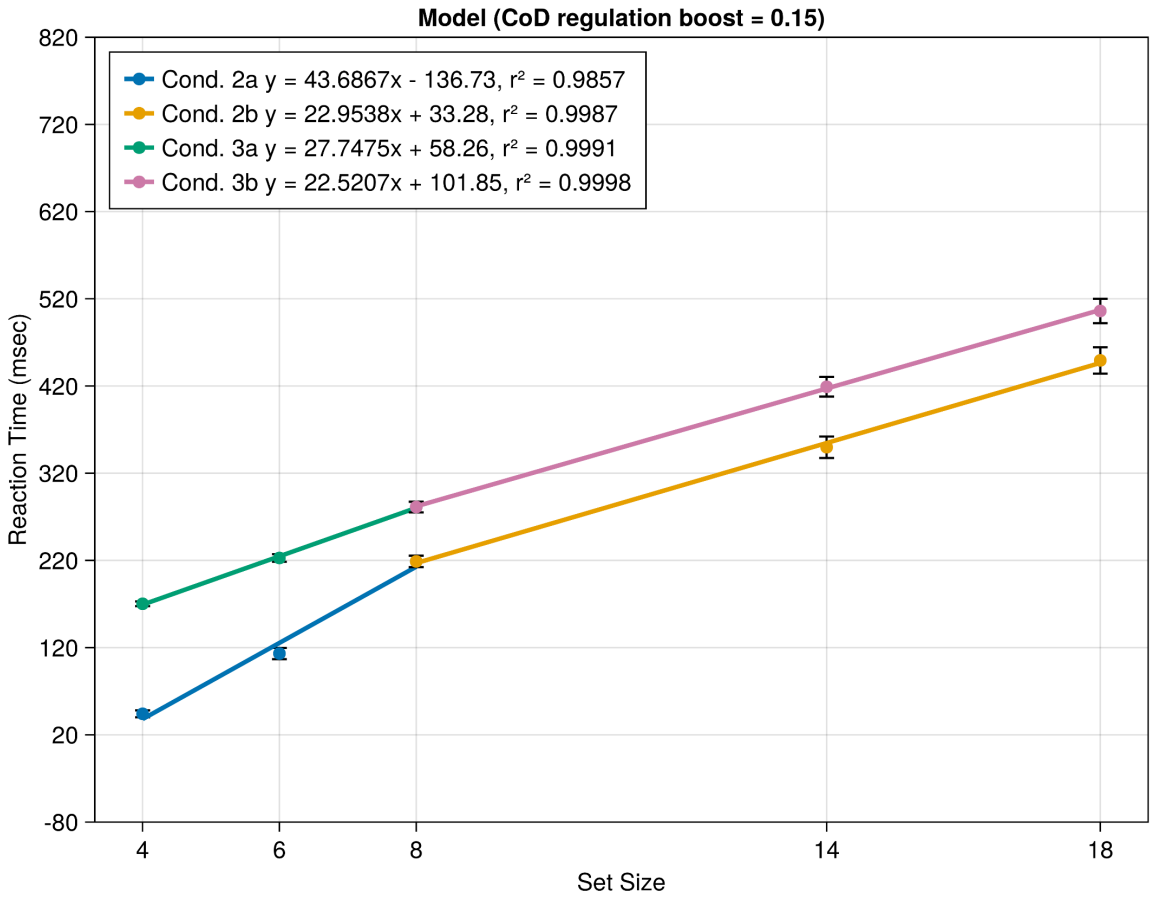
Model Results – Experiment 2



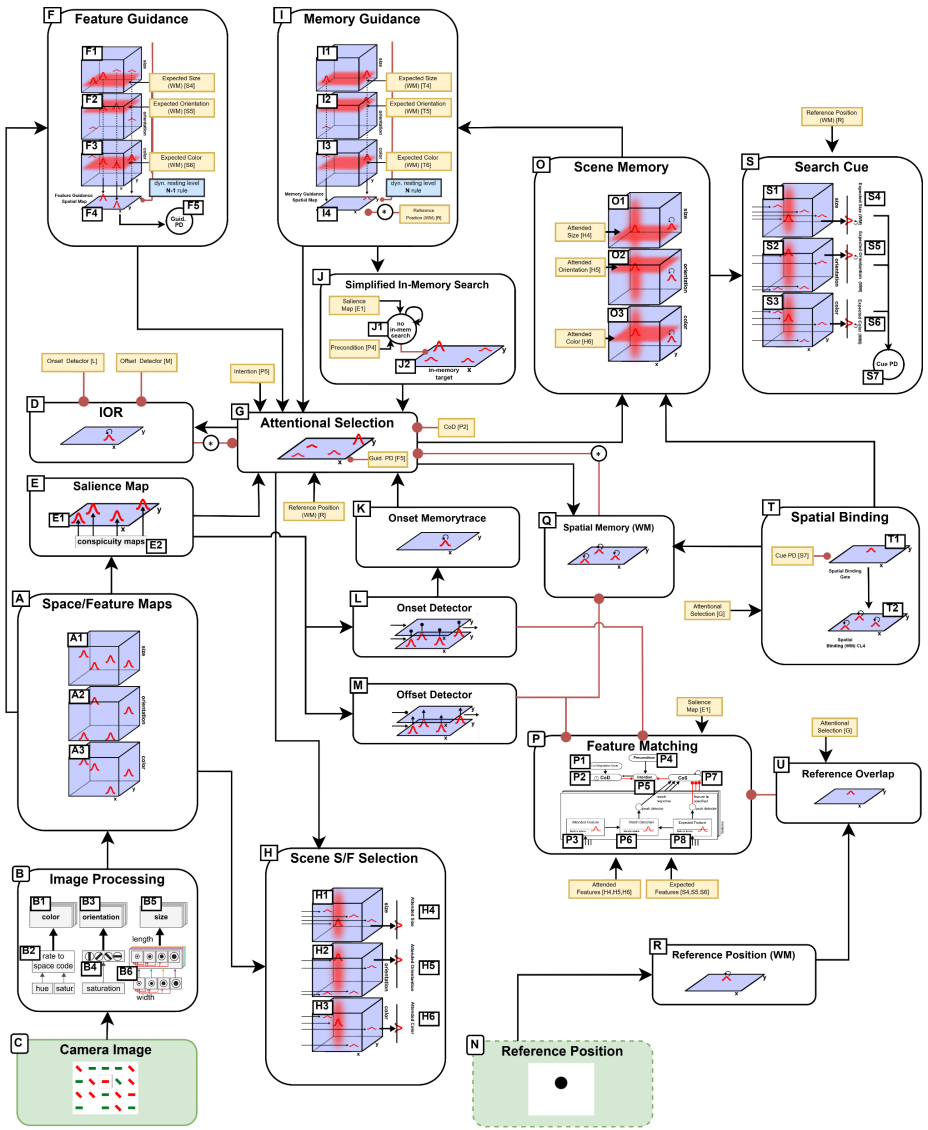


Model Results – Experiment 2





Model



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Questions?

Thank you for your attention!