Preattentive Segmentation of Objects from Backgrounds in Visual Search

Aude Oliva, Serena J Butcher & Jeremy M Wolfe

Harvard Medical School &
Brigham and Women’s Hospital, Boston.

Email: {oliva,serena,wolfe}@search.bwh.harvard.edu

Purpose

To study the effect of background *complexity* on visual search *efficiency*
(as measured by RT x set size slopes).

General Plan & Hypotheses

The Problem:

Previous research (and common experience) shows that observers can search through a relevant set of objects (e.g. all of the cars) in a complex scene (e.g. the parking lot). How do observers minimize or eliminate the effect of the background?

Experimental Strategy:

In each experiment, we keep the search task the same and vary the background complexity. We measure RT x set size functions.

Hypothesis One:

Each object must be separately extracted from the background. Increasing background complexity should add a cost for each item examined. Thus, slope of the RT x set size function should increase with background complexity.

Hypothesis Two:

A single operation separates possible target objects from the background. Search then proceeds through the set of target objects, ignoring the background. Eliminating more complex backgrounds may take longer but that is a "one -time cost". Thus, mean RT may increase with background complexity but slope should not.

Take-home message:

Hypothesis Two is the answer. "Clean-up" of the image is an initial step in search that has a cost. However, it is an additive RT cost and does not change search efficiency (measured by slope).

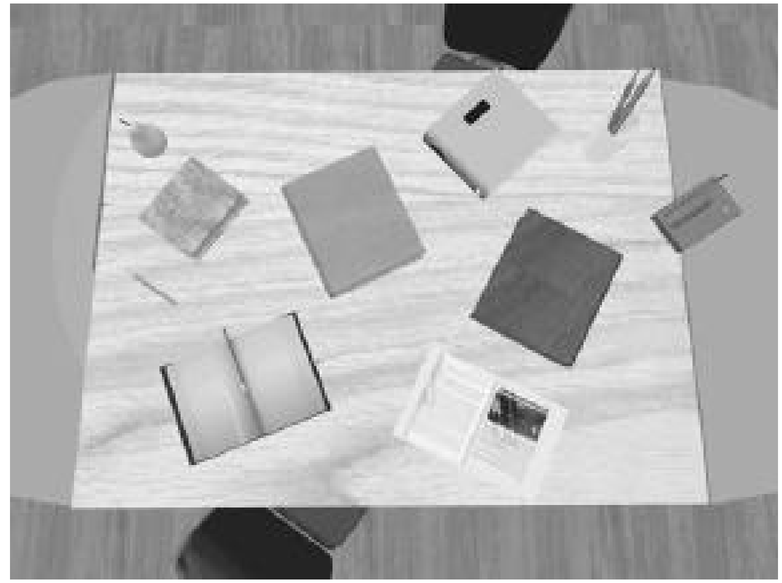
Experiment 1
Search among the desk

Purpose : In a realistic situation, subjects search for a specific object (e.g. a post-it, a pen, a key) among similar objects embedded in a background (e.g. a desk) of different complexity (messiness). Is the efficiency of the search affected by a cluttered background ?

Method : Three background desks of different complexity were composed using a 3D scene synthesis software. Complexity was measured as the number of irrelevant items (e.g. stuff on the desk). The target was the letter T designed to look like a refrigerator magnet. Distractors were Ls. 12 participants performed each 1000 experimental trials, searching for the T among 4, 8 or 12 letters.

Experiment 1 : Stimuli

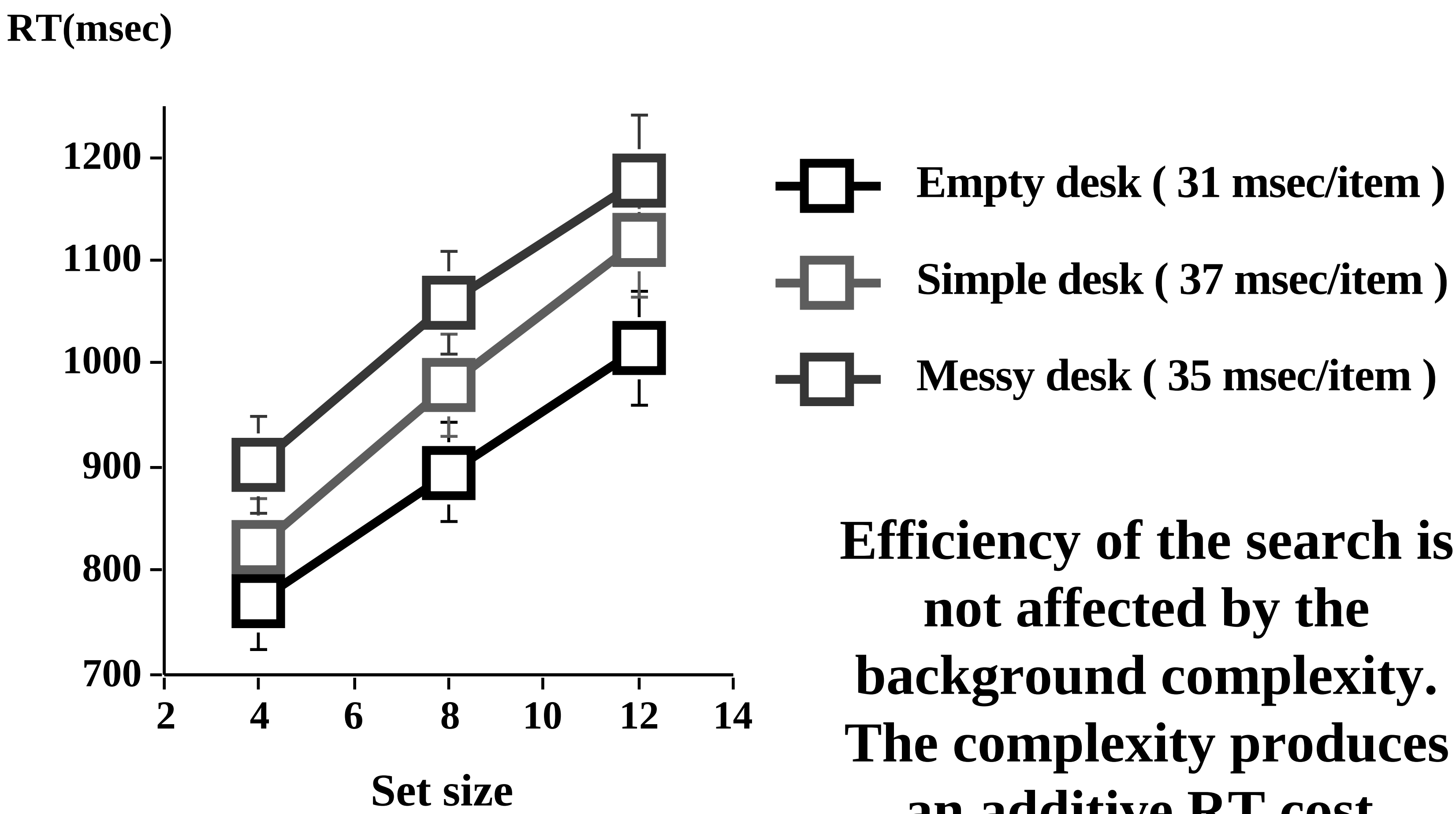
Empty desk



Simple desk

Messy desk

Experiment 1 : Results



Efficiency of the search is not affected by the background complexity. The complexity produces an additive RT cost.

Note: For target absent trials, slopes were respectively, 99, 105 and 105 msec/item.

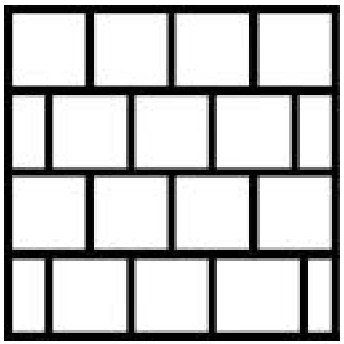
Thanks to Aline Bompas for her assistance in running this experiment.

Experiment 2
Search among brick walls

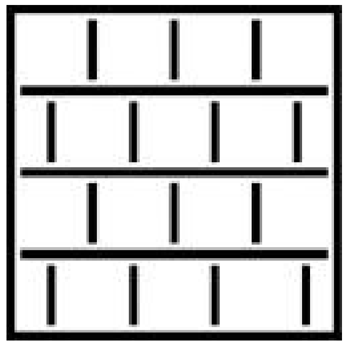
Purpose : In experiment 1, the background may not have been made of the same “features” than the features used for finding the candidates objects. Experiment 2 examined the ability of observers to separate search items from backgrounds composed of the same vertical and horizontal lines.

Method : Search task: target T among distractor Ls. Backgrounds varied in their similarity to the search items. Eight backgrounds were used, with 3 set sizes (3,6,9). 14 participants performed each a total of 2400 trials.

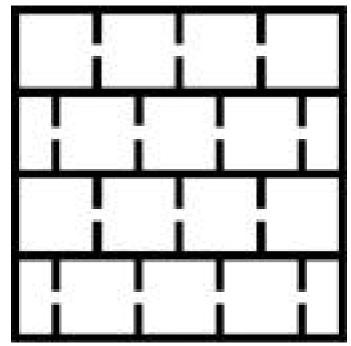
Experiment 2 : The eight backgrounds



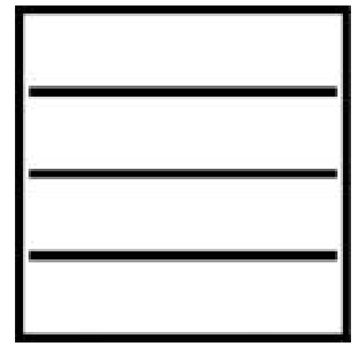
T junctions



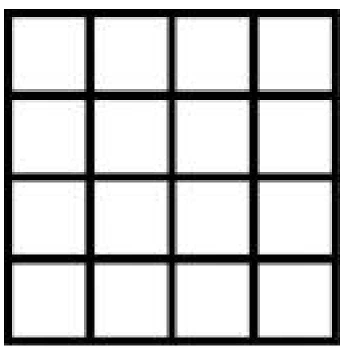
“Broken” T junctions



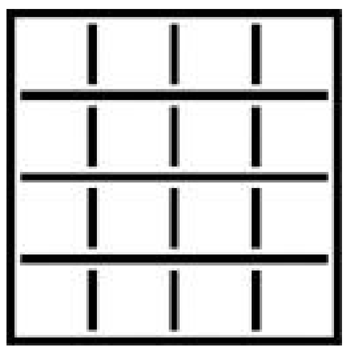
T Junctions w/line terminator control



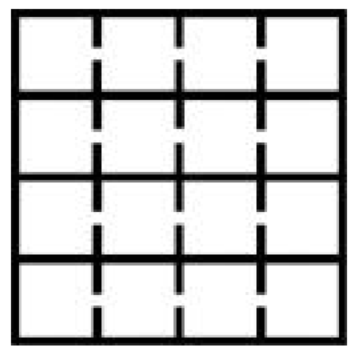
No junctions no vertical



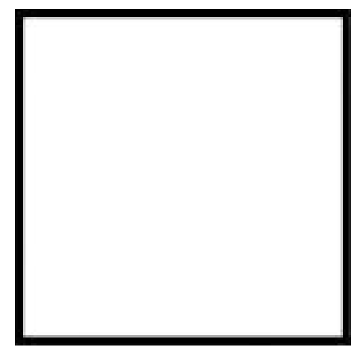
X junctions



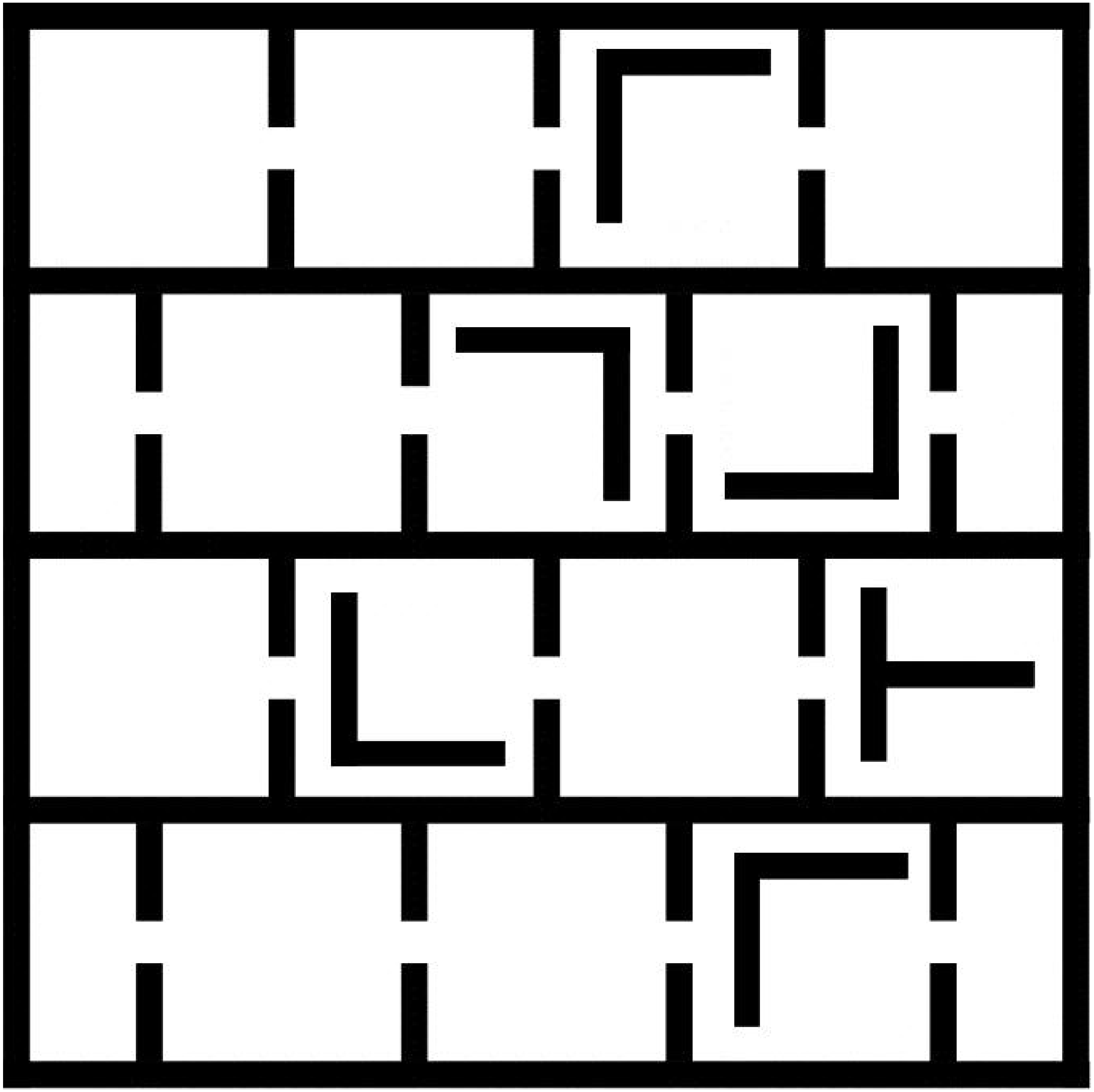
“Broken” X junctions



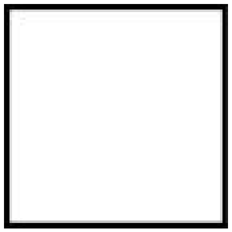
X Junctions w/line terminator control



Blank square control

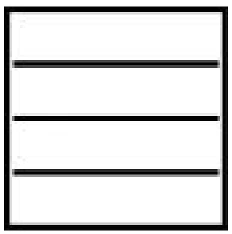


Experiment 2 : Results



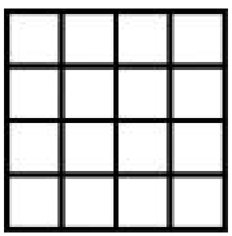
Slope = 17 msec

Mean = 562 msec



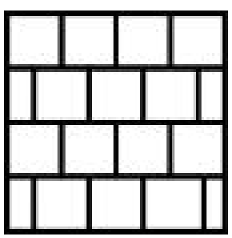
Slope = 16 msec

Mean = 580 msec



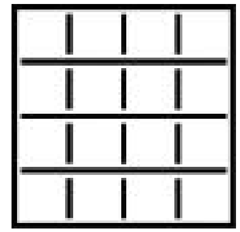
Slope = 17 msec

Mean = 587 msec



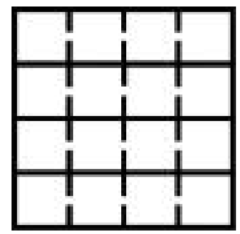
Slope = 22 msec

Mean = 596 msec



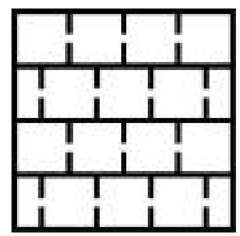
Slope = 21 msec

Mean = 618 msec



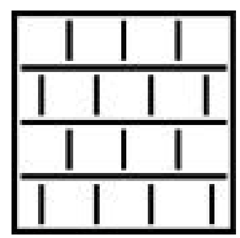
Slope = 18 msec

Mean = 628 msec



Slope = 24 msec

Mean = 637 msec



Slope = 21 msec

Mean = 664 msec

Again, efficiency of search (slope) is not affected by the background complexity.
The complexity produce an additive RT cost.
Results favor the “clean-up” hypothesis (#2).

Experiment 3
Camouflaged Target

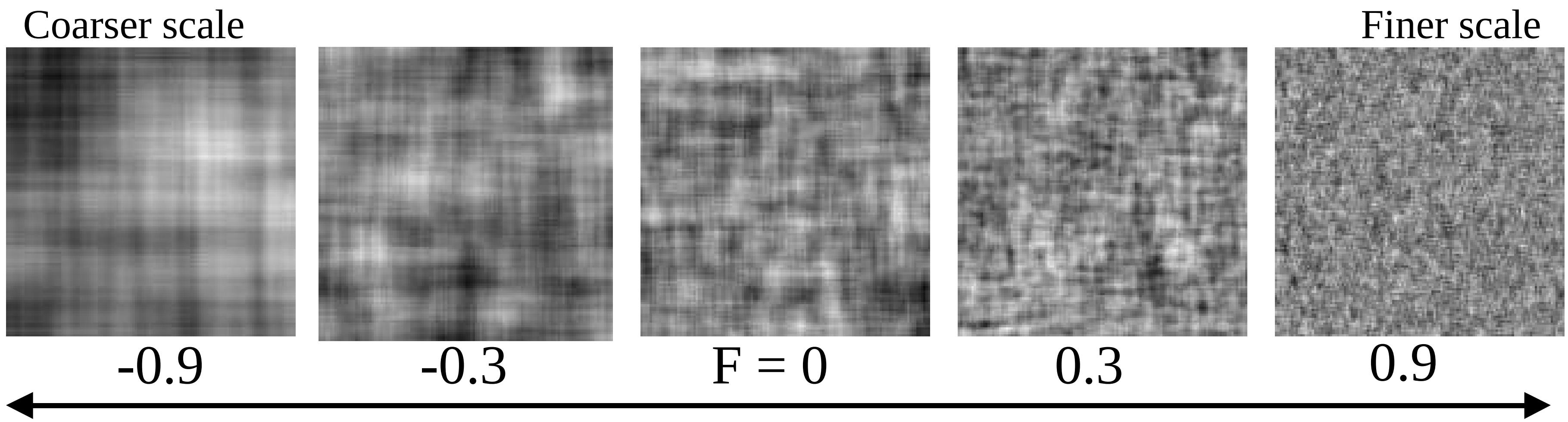
<u>Purpose :</u> To systematically vary the similarity of target and background spatial frequency (SF) content.

<u>Method :</u> Backgrounds were textures composed of the same spatial frequencies as the target or of a lower SF component (.5x and 0.125x) or of an higher SF (2x and 8x). We plot relative log SF from low to high SF. (-0.9,-0.3,0,0.3,0.9 relative log units). Participants performed two search tasks: searching for <u>one</u> target or searching for <u>two</u> targets. Set sizes were 1,4,7,10 items.

<u>Logic:</u> If clean-up is done only once, then the cost of the background will be similar for 1T and 2T tasks.

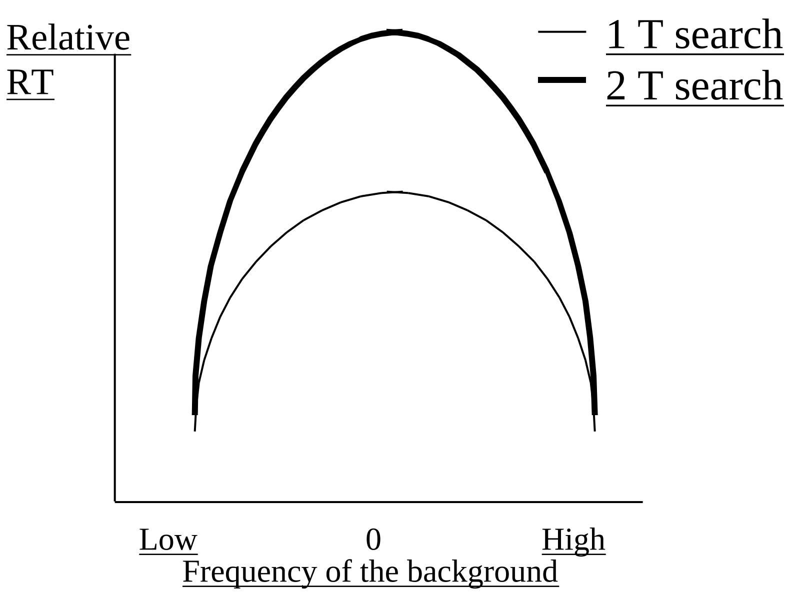
All the backgrounds had the same histogram (a gaussian distribution of gray-level). The targets and distractors were of different contrasts: 3 stdev (easely discriminable), 2 stdev and 1 stdev((almost "camouflaged") from the background mean.

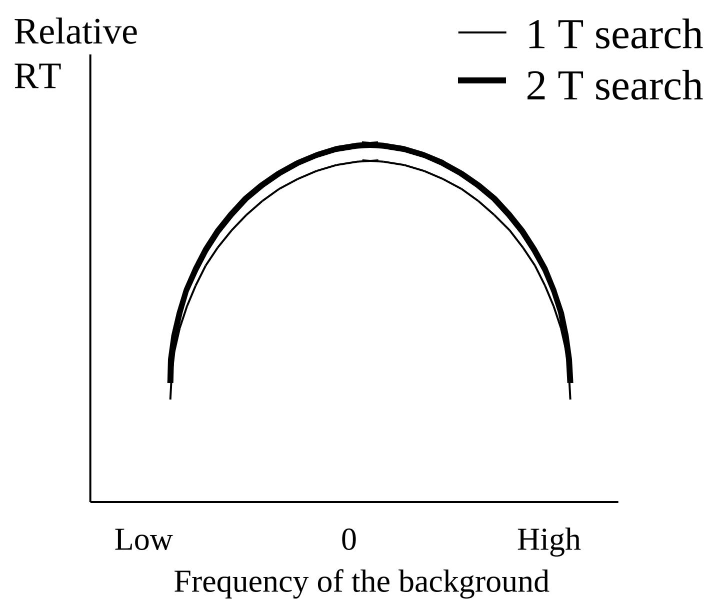
Experiment 3 : Camouflage patterns

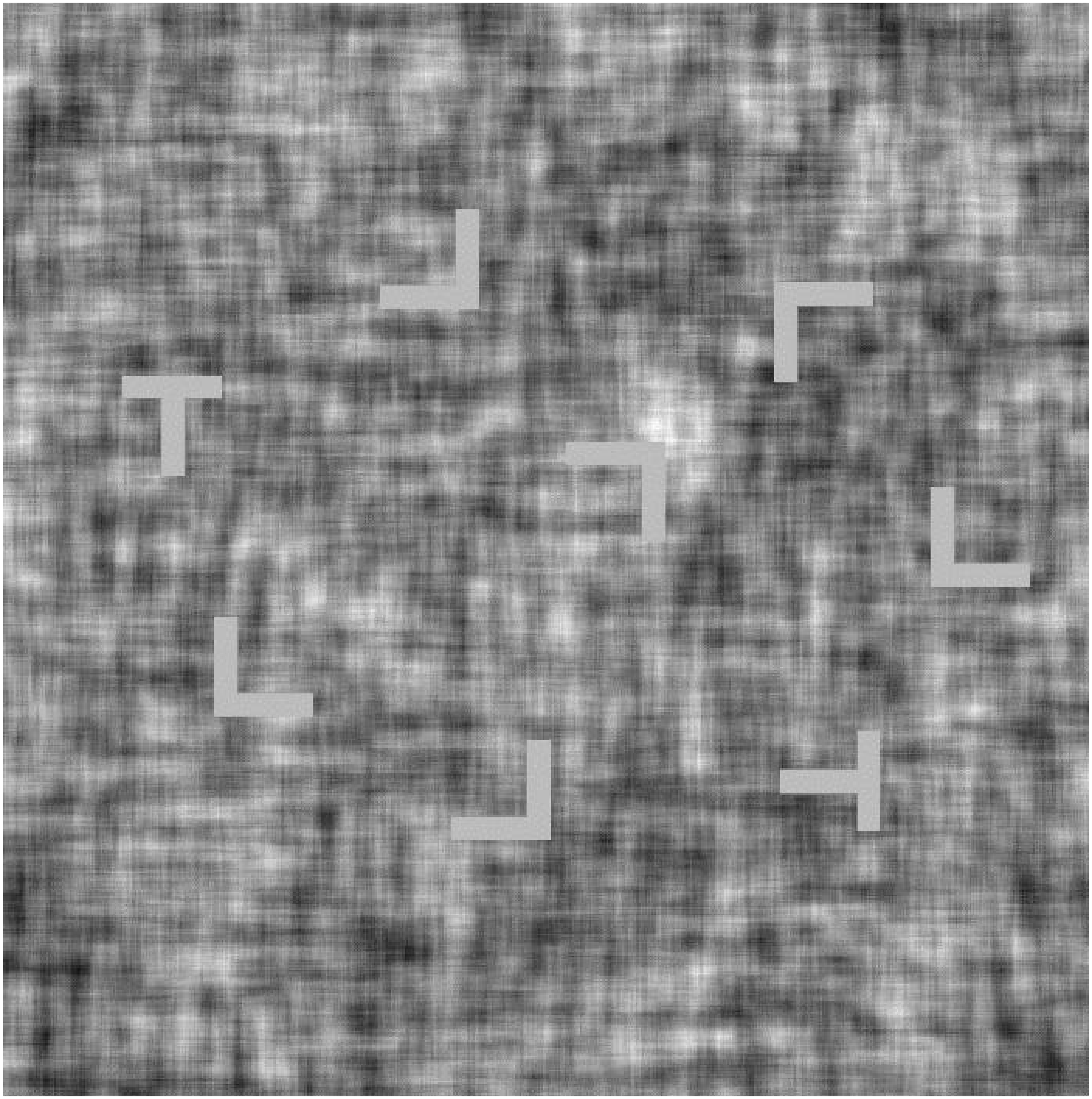


Hyp 1: Clean up twice (once for T1, again for T2)

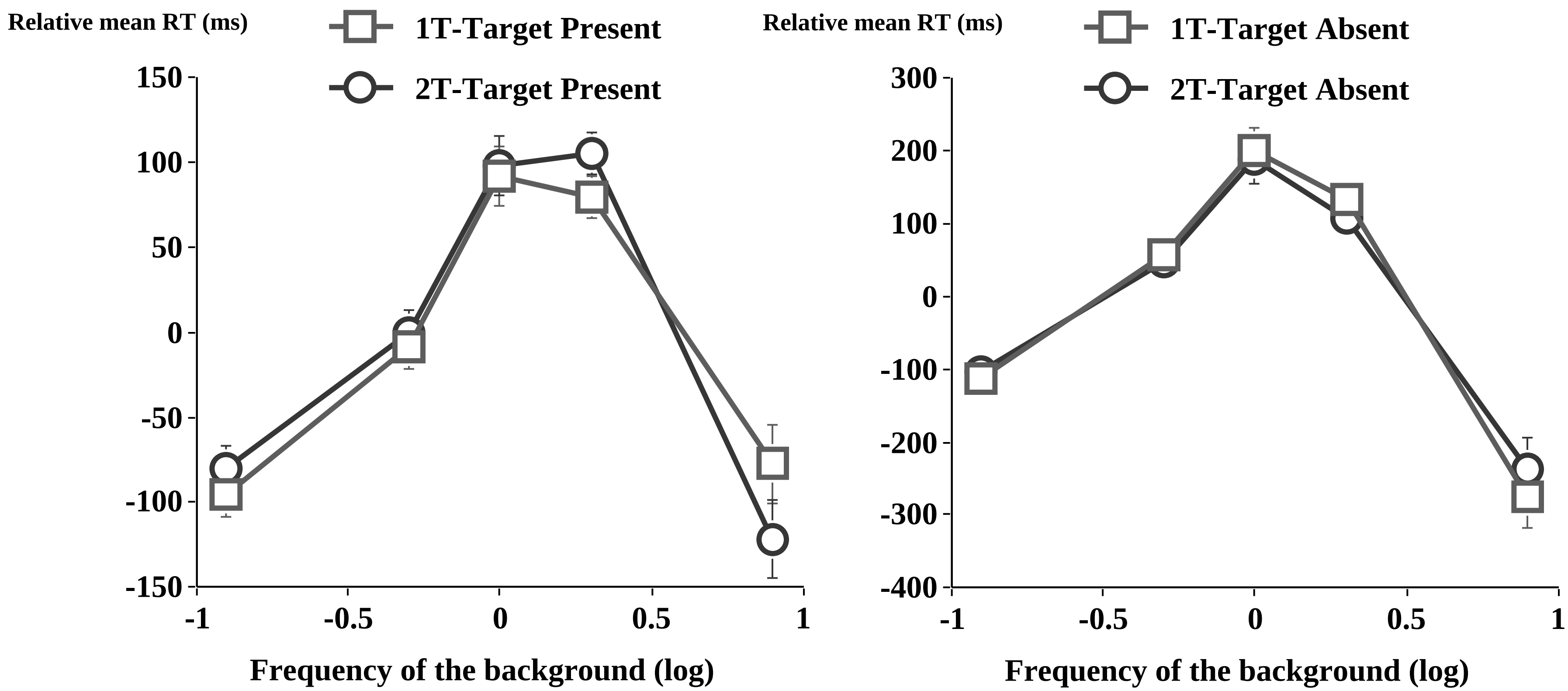
Hyp 2: Clean up once







Experiment 3 : Results



Slopes for 1 Target =44,31,51,44,37 msec/item (not significant)
Slopes for 2 Targets =80,80,80,84,80 msec/item (not significant)

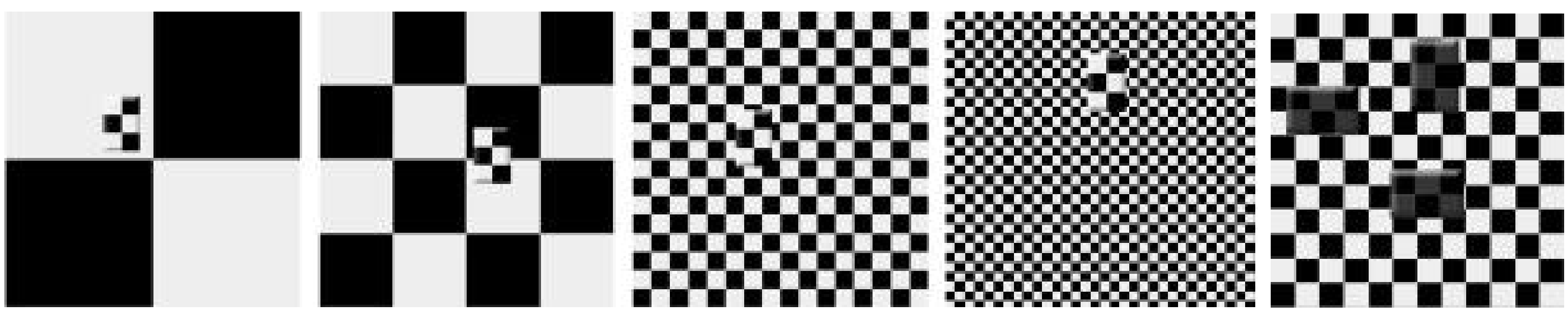
Slopes for 1 Target =99,95,84,92,102 msec/item (not significant)
Slopes for 2 Targets =140,123,122,132,145 msec/item (not significant)

Efficiency of the search (slope) is not affected by the background complexity. The complexity produces an additive RT cost that is dependent on the spatial frequency similarities between the target and the background . Results in favor of the "clean-up" hypothesis (#2).

Experiment 4 : “The needle in the haystack”

Purpose : Sometimes targets must get lost in the background. If we make the background *very* similar to the search items, then we should reduce search efficiency.

Method : Subjects searched for 3x2 (vertical) checkerboard patches among 3x2 (horizontal) patches. Backgrounds were checkerboards. Background checks sizes ranged from 1/16 to 16 times the size of the search item checks. Backgrounds were yellow and black. Search items were either the same color or different (red and black). The search items were not aligned with the background. Otherwise they would be invisible when background and search items had the same check size and color. Set sizes of 1, 3, & 5 were tested.



Frequency F/8
Complexity = log(0.125)

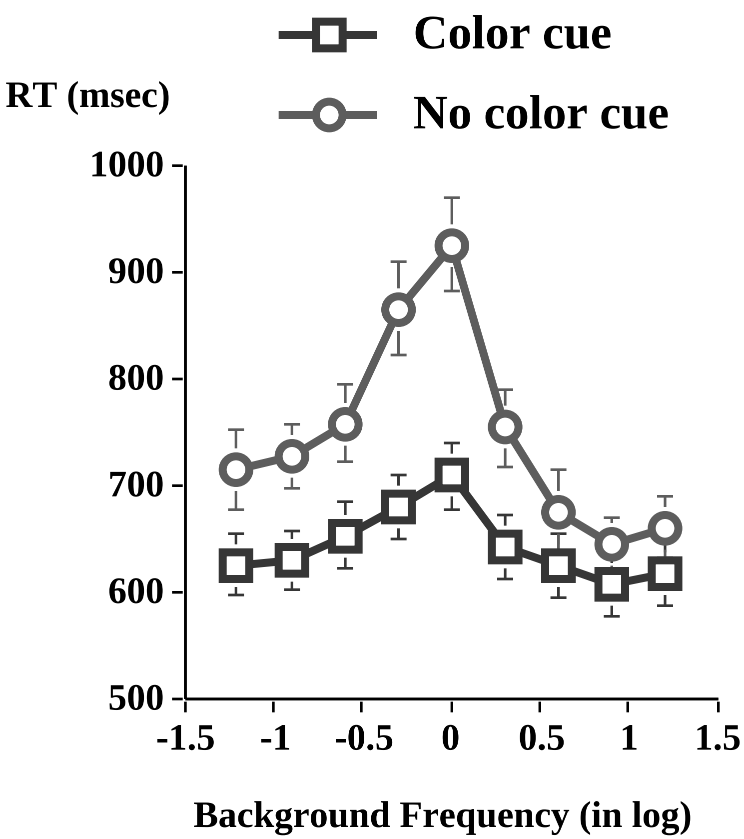
Frequency F/4
Complexity = log(0.25)

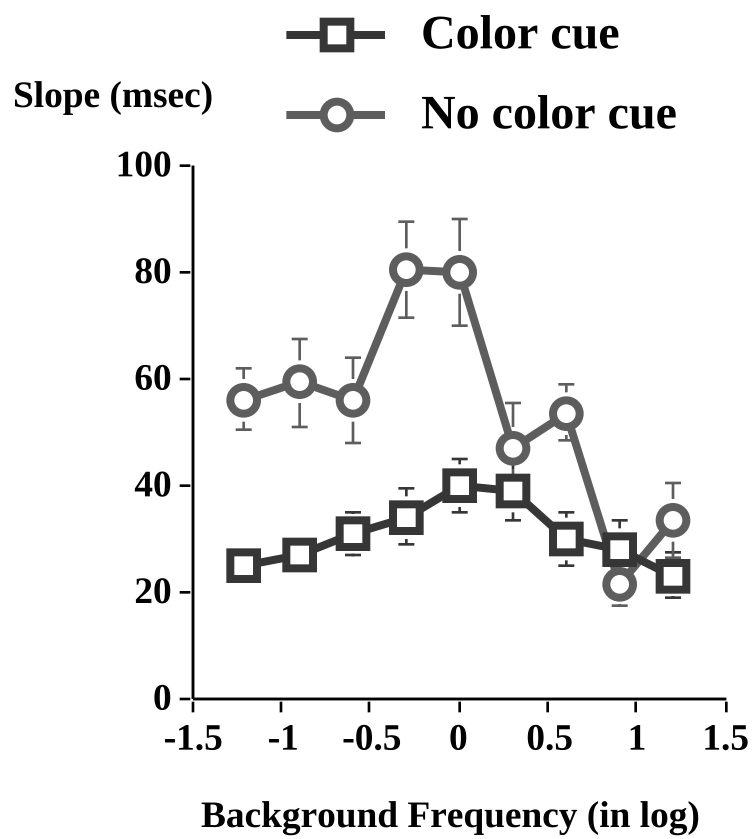
Frequency F
Complexity = Max

Frequency 2F
Complexity = log(2)

background
with color-cue stimuli

Experiment 4: Results





Similarity of background and search items has an effect on RT *and* on slope. When scene segmentation is very hard, search efficiency drops. Note that search efficiency is reduced even if search items differ in color from the background.

Conclusions

1. Observers can separate candidate targets from the background in a single "preattentive" step.

2. The time for that step varies with background complexity and/or similarity to the search items but that time is additive with search time.

3. Search efficiency can be lowered but only by making the background very similar to the search items.

Next step: Can we develop a model of the process that separates search objects from the background?

A pdf file of this poster can be downloaded at: http://search.bwh.harvard.edu/