Feature Transitions with Saccadic Search: Size, Color, and Orientation Are Not Alike

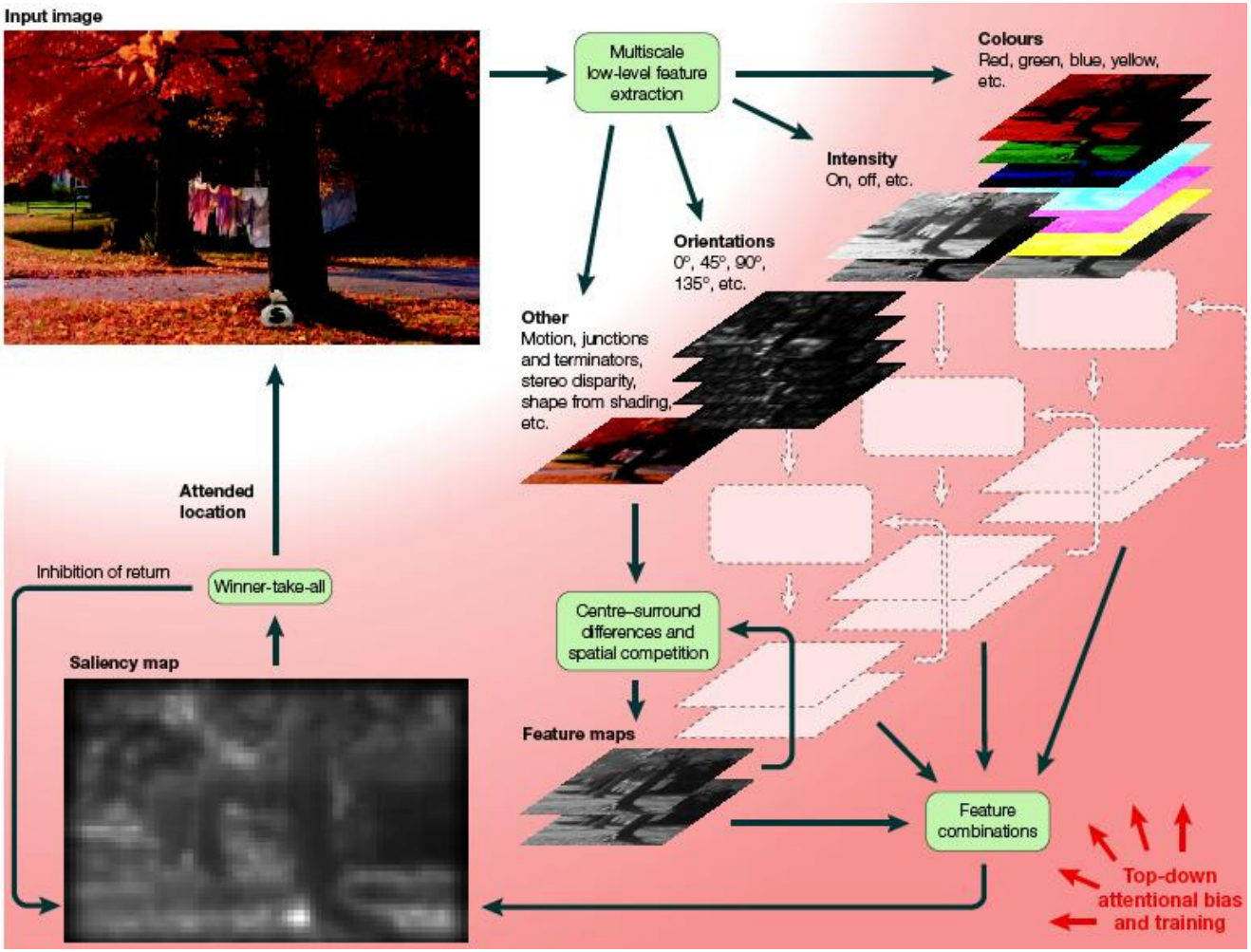
Stella X. Yu

Computer Science

Boston College

NIPS 2010

Size, Color, and Orientation: Elementary Features



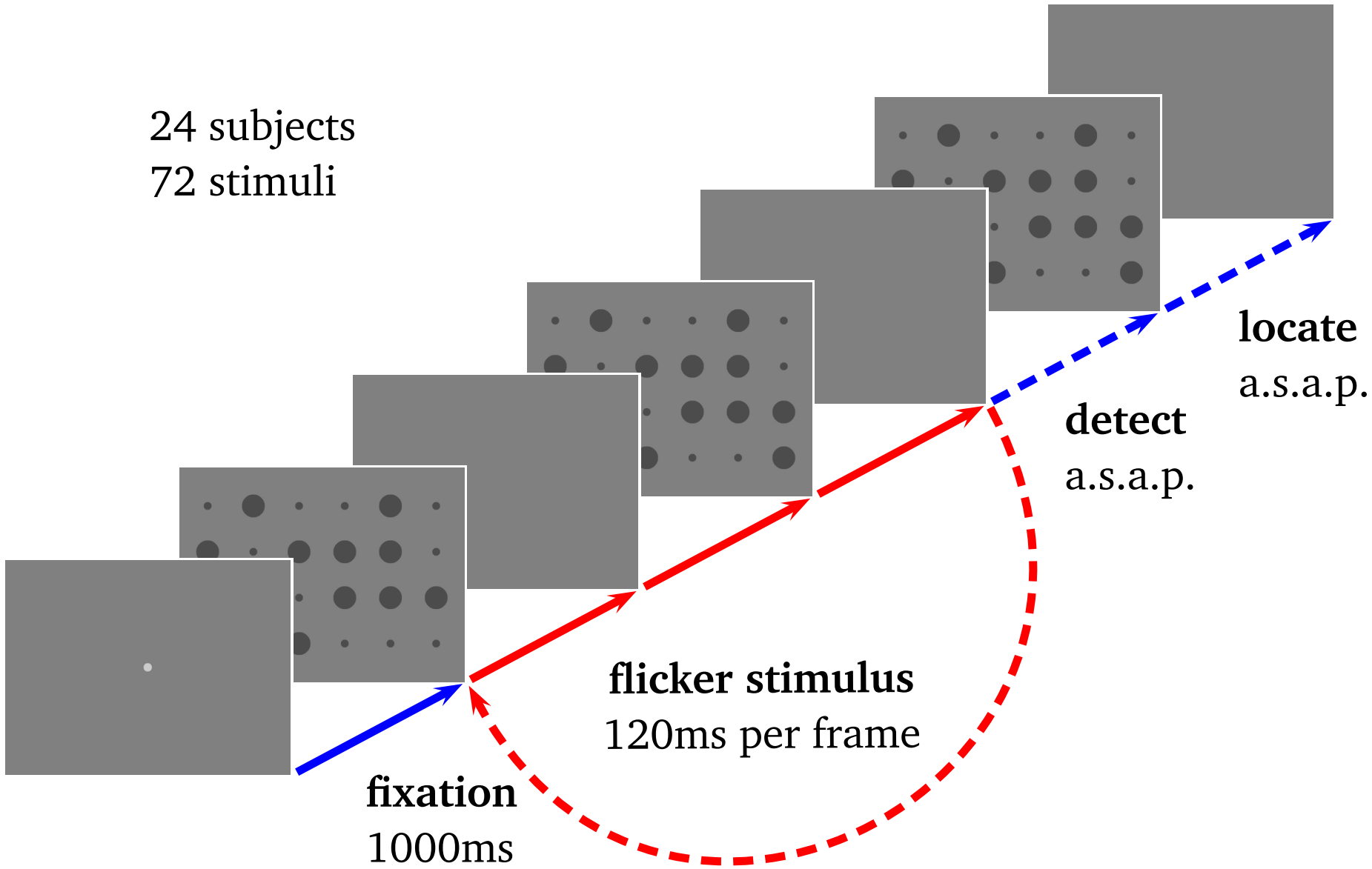
Do these elementary features
with alike parallel local detections in space
have alike serial deployment of attention over time?

Saccadic Search Depends on Feature/Filter Type?

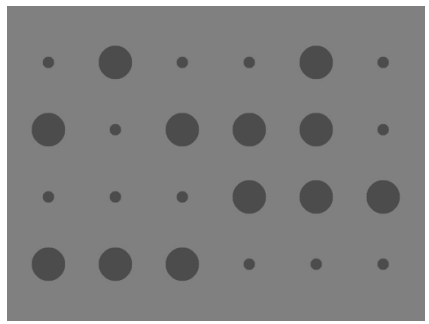
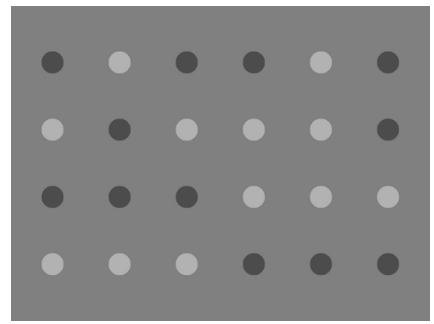
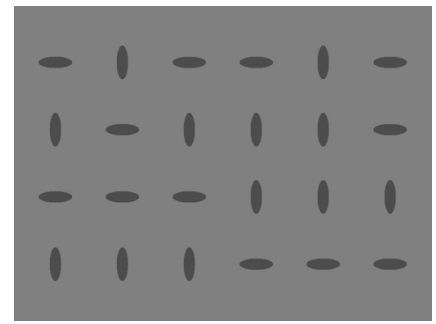
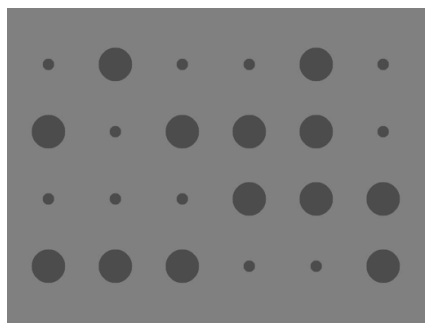
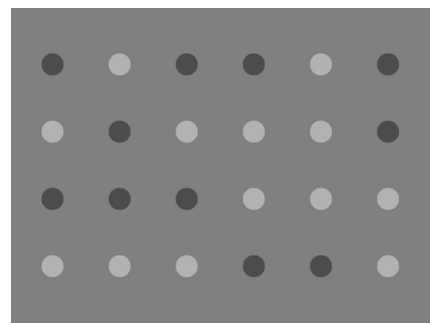
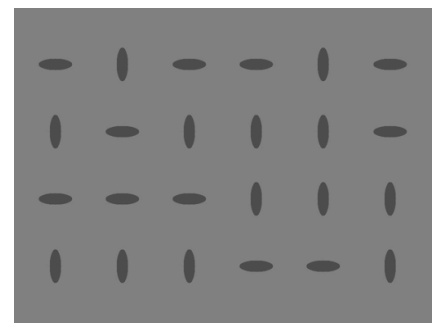
disk1	disk2	disk1	disk1	disk2	disk1
disk2	disk1	disk2	disk2	disk2	disk1
disk1	disk1	disk2	disk2	disk2	disk2
disk2	disk2	disk1	disk1	disk1	disk1

If attention depends only on the spatial map of responses regardless of which filters produce them, there should be little differences in the saccadic search for a flickering target among identically laid out disks rendered in comparable attributes of different features.

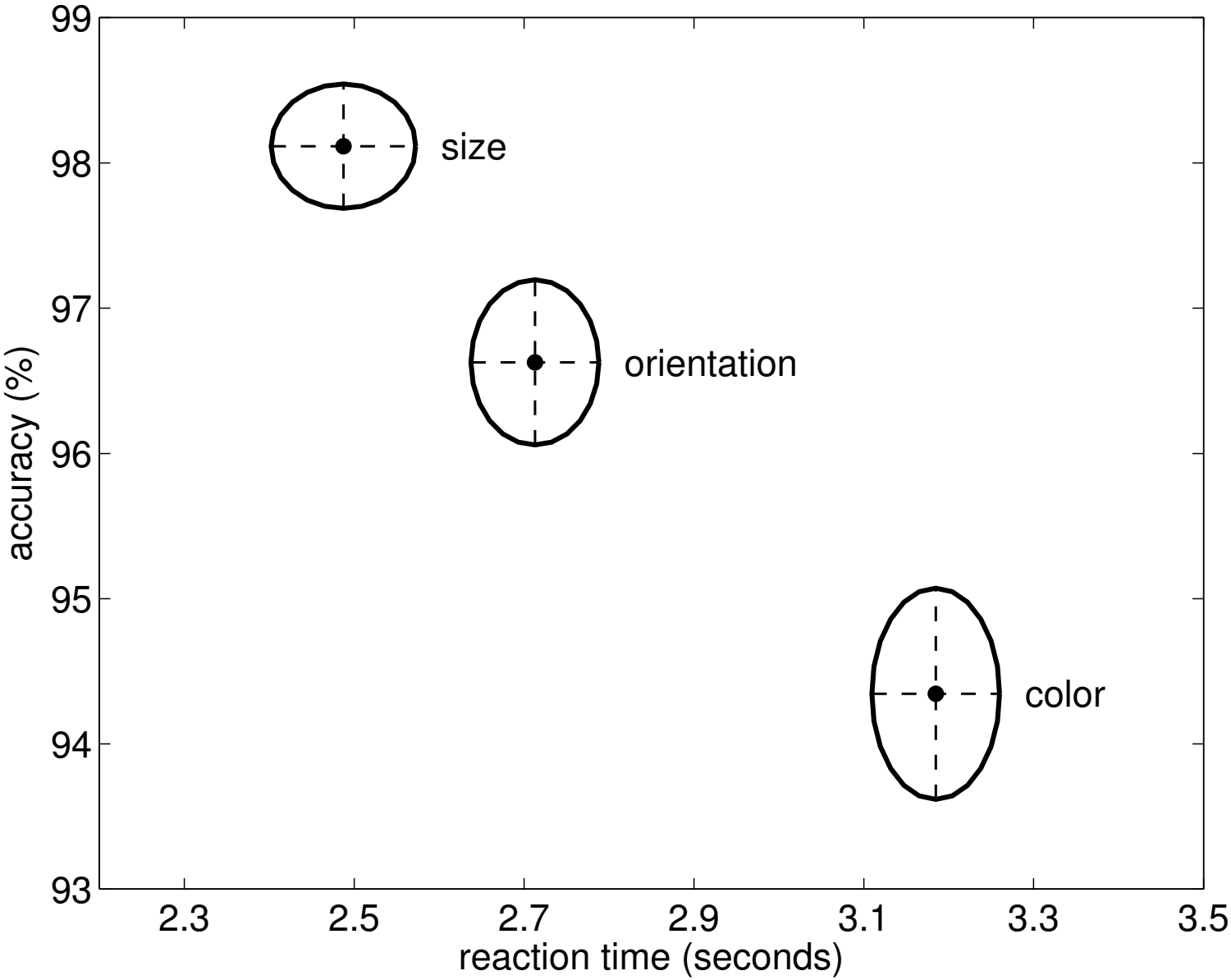
Change Detection and Localization Experiment



Stimuli: Different Features in Identical Layout

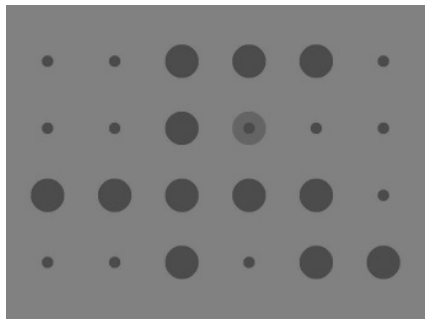
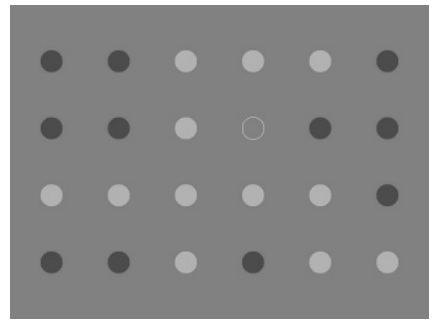
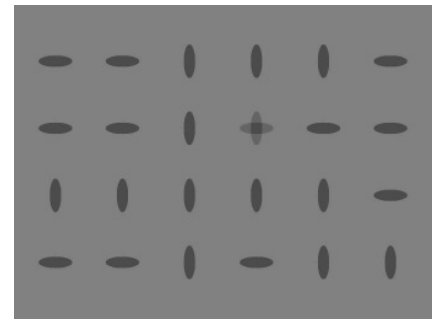
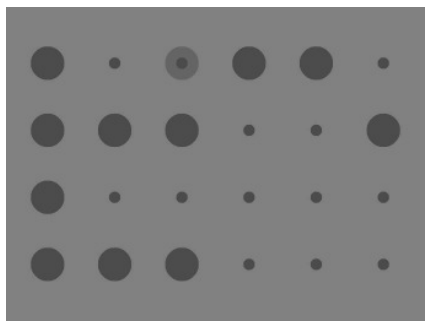
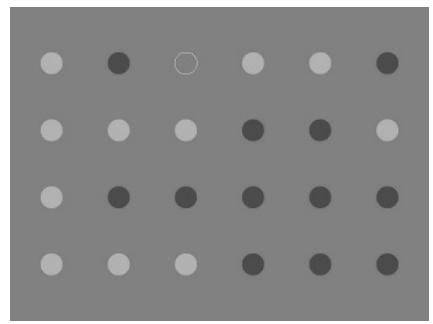
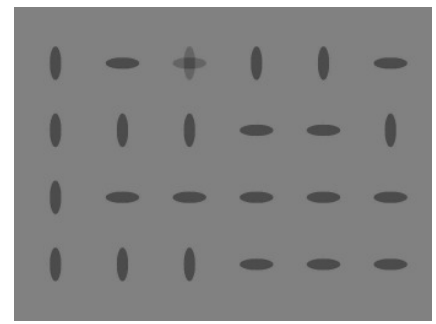
flicker stimuli	**size**	**color**	**orientation**
identical layout	 1 2	 1 2	 1 2
1st image 1 2 1 1 2 1 2 1 2 2 2 1 1 1 1 2 2 2 2 2 2 1 1 1			
2nd image 1 2 1 1 2 1 2 1 2 2 2 1 1 1 1 2 2 2 2 2 2 1 1 2			

Overall Saccadic Search Performance



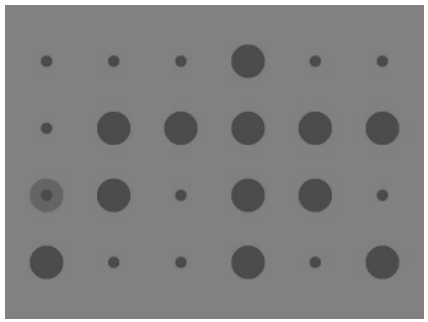
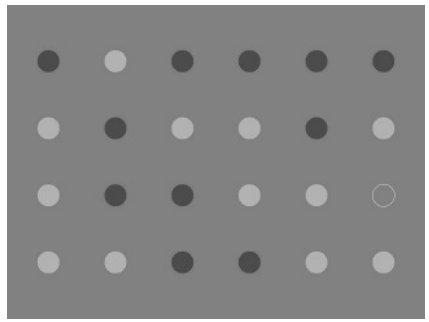
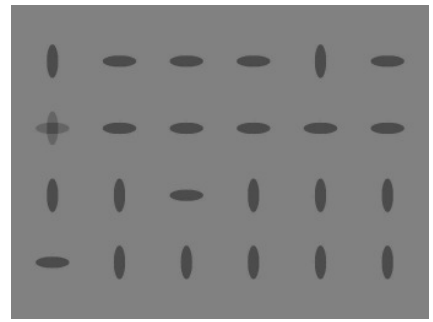
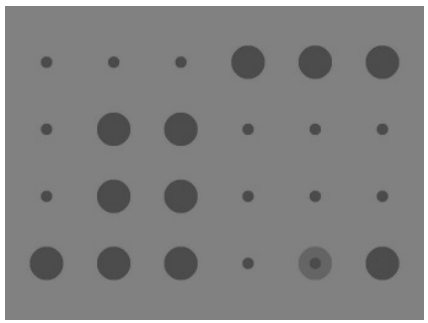
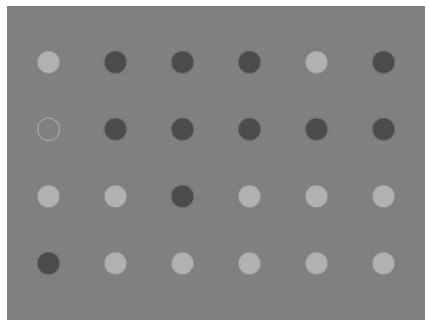
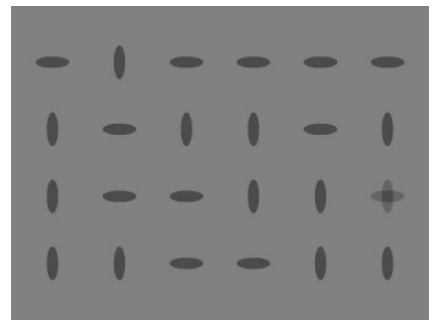
Impact of Spatial Context on Detection: Common

Change is easier to detect in a homogeneous neighbourhood.

commonly best layout	 (100%, 1.36 s)	 (100%, 1.52 s)	 (100%, 1.20 s)
commonly worst layout	 (83%, 11.98 s)	 (78%, 4.18 s)	 (78%, 5.88 s)

Impact of Spatial Context on Detection: Specific

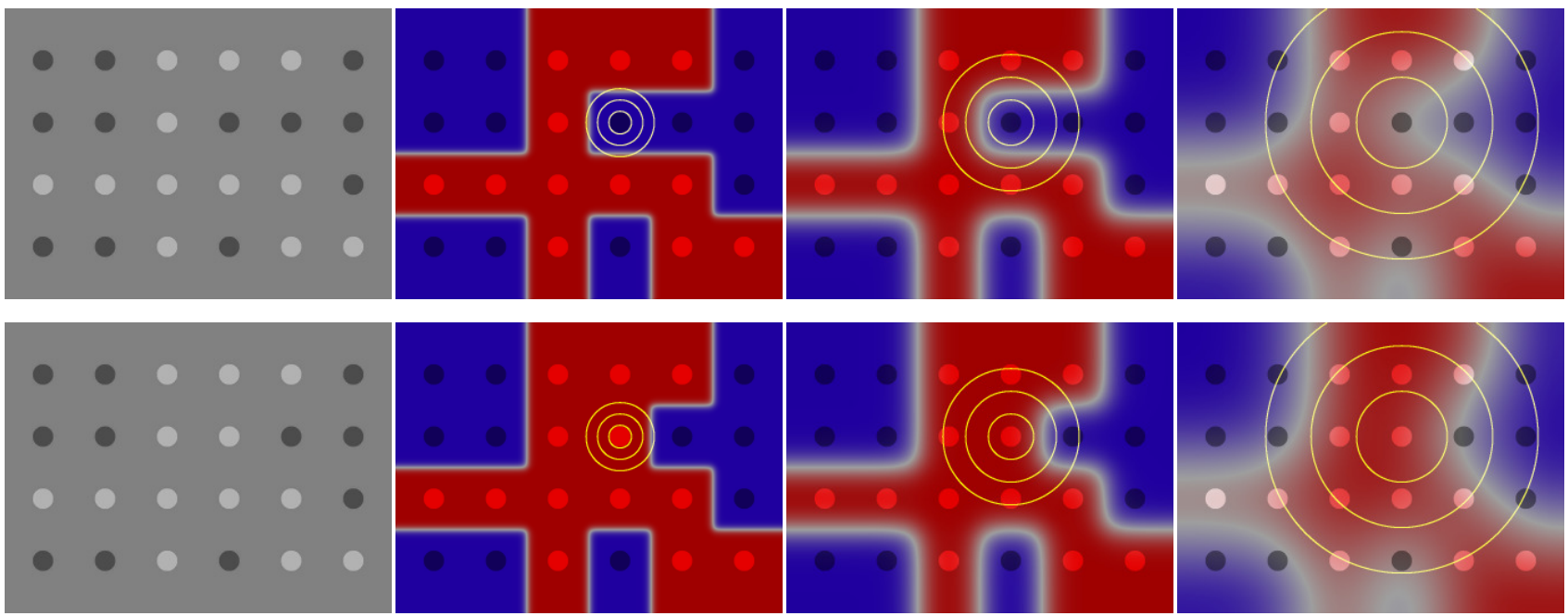
... only if the items are large for size, or collinear for orientation

dimension specific best layout			
	(100%,2.34 s) (83%,5.44 s) (83%,6.47 s)	(100%,3.08 s) (100%,2.09 s) (80%,2.35 s)	(94%,3.37 s) (78%,4.08 s) (94%,2.69 s)
dimension specific worst layout			
	(90%,2.10 s) (100%,2.65 s) (100%,2.59 s)	(94%,3.37 s) (78%,4.08 s) (94%,2.69 s)	(100%,3.08 s) (100%,2.09 s) (80%,2.35 s)

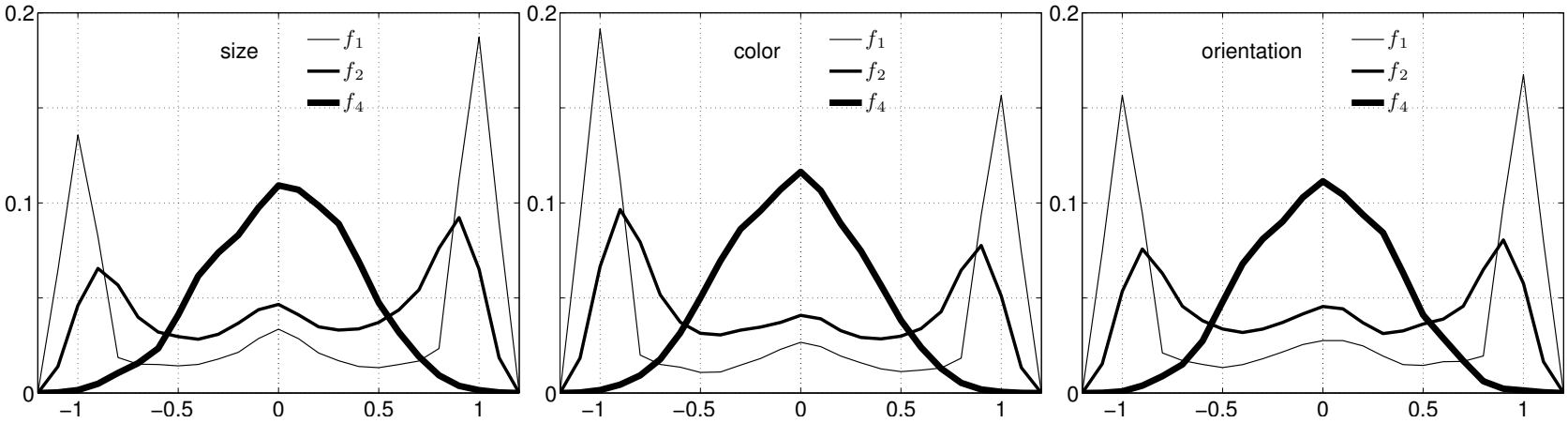
Neighbourhood Uniformity: f-numbers

$$f_0(i) = \begin{cases} 0, & \text{no disk at } \mathrm{loc}(i) \\ -1, & \text{disk type 1 at } \mathrm{loc}(i) \\ 1, & \text{disk type 2 at } \mathrm{loc}(i) \end{cases}, \quad f_\sigma(i) = \frac{\sum_j f_0(j) G(\mathrm{dist}(i,j);\sigma)}{\sum_j G(\mathrm{dist}(i,j);\sigma)}$$

f_0 f_1 f_2 f_4



Fixational Bias in the Spatial and Featural Domains



marginal probability distribution of f_1, f_2, f_4 from all the fixations

1. common spatial bias
   - fixating disks instead of empty spaces
   - fixating disks separating large uniform groups
2. dimension-specific attribute bias
   - large for size, black for color, vertical for orientation

Saccadic Bias in the Featural Domain

size				color				orientation			
π_a	$P_{b\|a}$			π_a	$P_{b\|a}$			π_a	$P_{b\|a}$		
.43	.40	.10	.50	.52	.53	.09	.38	.46	.44	.08	.48
.04	.36	.15	.49	.04	.33	.16	.51	.04	.44	.12	.44
.53	.37	.12	.51	.44	.48	.09	.43	.50	.43	.10	.47
attractive bias				repulsive bias				reversible bias			

- π_a is the overall probability of visiting feature a
- $P_{b|a}$ is the probability of saccading to feature b at feature a

Summary

- That saccadic search is most effective in size and worst in color cannot be due to their alike local detectors in space, but is due to their selective biases in the spatial and featural domains over time.
- Focusing on the large group essentially cuts down the search space by half, whereas excursion into the white from the primary black group only hurts the spatial efficiency of search.

Funding: NSF CAREER IIS-0644204
Clare Boothe Luce Professorship