PROCESSING OF IMAGE STATISTICS WITH AND WITHOUT SEGMENTATION CUES

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INTRODUCTION

Statistical aspects of images are cues for texture discrimination and segmentation. In pre-segmented patches (VSS 2003), discrimination of local 1st order structure (luminance: LUM) and local 4th order structure (isodipole textures: EVEN) is much more efficient than that of non-local 2nd order structure (mirror symmetry: SYM), despite its visual saliency. This and other evidence suggests that symmetry detection uses a different computational substrate than processing of local statistical structure. Here we compare the relationship of these three statistical image classes to segmentation.

STIMULI & METHODS

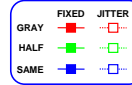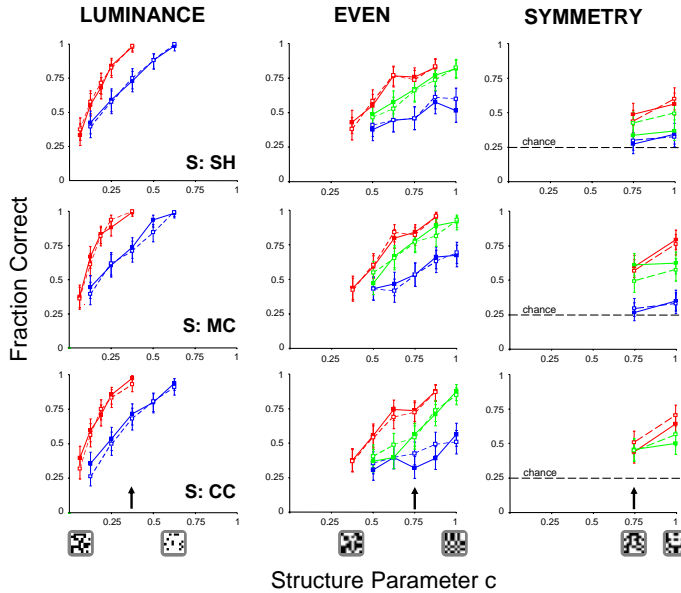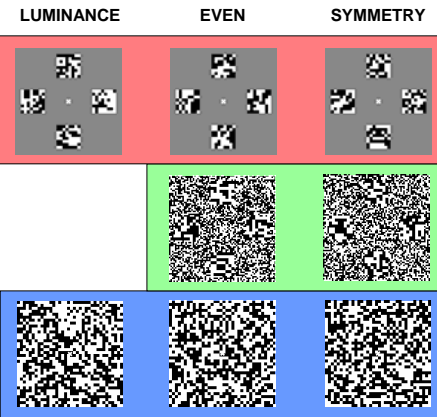**TASK: Which one of the four arrays is different?**
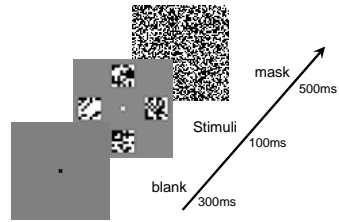
Stimuli contained four arrays: three distractor arrays colored at random, and a single target array, drawn from one of three images classes illustrated below. Each image class was defined by a single statistical attribute: luminance (LUM), local fourth-order correlation (EVEN), or long-range statistics (SYM).

Stimuli consisted of four 8x8 arrays of black and white checks (check size: 20 min, test distance: 103 cm). Arrays were positioned either 4 degrees from fixation along the cardinal axes (fixed) or in "jittered" locations about the fixation point to introduce positional uncertainty.

Stimulus duration was 100ms.

Practiced observers (N = 5) were asked to identify the target in a 4-AFC task. Dependent measures were fraction correct (FC) and reaction time (RT).

Each observer completed a total of 8,480 trials over six sessions. A block of trials consisted of a single image class, a single background, and a single jitter condition. Each session consisted of blocks with two of the three image classes, and all background and jitter conditions.

Other Details:

Examples of each image class were generated with a range of statistical structure, "c" (c = 0 corresponds to randomness, and c = 1 corresponds to all-white, fully-even, or completely symmetric). Values of c were chosen to span the range of psychophysical performance.

Feedback during practice (1-2 hrs) only
Contrast: 1.0; Luminance: 47 cd/m²
Cambridge Research VSG2/5 system

Image Classes and Background Conditions

LUMINANCE   EVEN   SYMMETRY

GRAY background at mean luminance

HALF-sized random checks

SAME-sized random checks

LUMINANCE   EVEN   SYMMETRY

Fraction Correct

S: SH

S: MC

S: CC

Structure Parameter c

FIXED JITTER
GRAY
HALF
SAME

chance

RESULTS FROM INDIVIDUAL SUBJECTS (3 of 5 shown)

Do the image statistics alone segment the arrays? It depends.
LUM (FC = .72) **YES**; EVEN (FC = .44) **YES**; SYM (FC = at chance) **NO**

Are some segmenters better than others? YES. Segmentation is NOT all-or-none.
For EVEN and SYM, the HALF background results in an intermediate fraction correct. For LUM, fraction correct is high (.72) for the SAME background, and near perfect (.98) for the GRAY background.

Does positional uncertainty matter? NO.
There was no difference in fraction correct for fixed vs. jittered targets, for any image class and any background condition.

What about the Reaction Time?
Image classes or background conditions that had a higher fraction correct had shorter reaction times.

RESULTS   N = 5

Data are averaged across subjects at an intermediate c-level indicated by ↑ above.

FIXED JITTER
GRAY
HALF
SAME

Fraction Correct

LUMINANCE   EVEN   SYMMETRY

➤ For luminance and the even texture, fraction correct without segmentation cues (SAME) was .72 and .44 respectively; and increased when a segmentation cue (GRAY) was provided (LUM FC = .98; EVEN FC = .70).

➤ For symmetry, detection without a segmentation cue (SAME) was at chance performance, but increased for HALF (.43) and GRAY (.46).

➤ For all image classes, positional uncertainty (fixed vs jittered) did not affect performance.

Localization vs Segmentation   N = 5

METHODS

N = 5 trained subjects
4-AFC task (15,840 trials/subj)

4 Image Classes
Luminance
Even Textures
1D-correlated
Symmetry

8x8 "jittered" arrays on SAME - size check bkgds

Stimulus Duration: 100 ms.

4 Cueing Conditions
SAME Bkgd (NoCue)
Red Vertical Bar
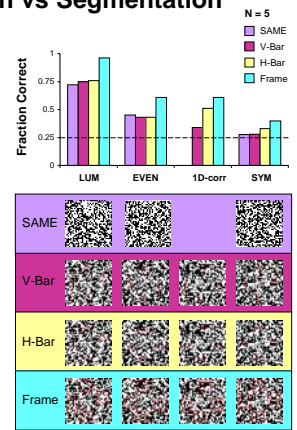Red Horizontal Bar
Red Frame

RESULTS

Fraction correct for LUM was highest overall; regardless of cueing.

The Frame cue elicited the highest fractions correct for all image classes.
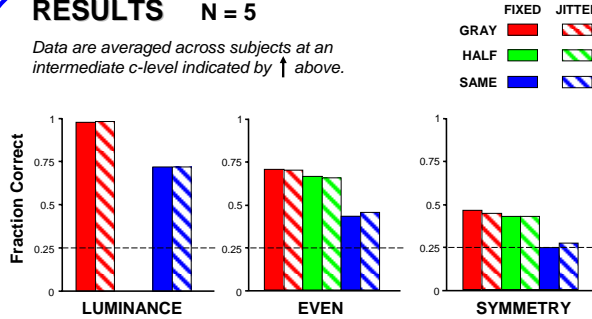
For LUM/SAME, fraction correct was .72, and increases with the Frame cue to .96, comparable to the LUM/GRAY (.98) condition reported above.

V-Bar and H-Bar conditions localize but don't segment. They do not result in an improved FC for LUM, EVEN, or SYM, as we expected from the lack of an effect of positional uncertainty. However, H-Bar *does* result in an improved FC for the 1D-correlated images. This suggests an orientation-specific interaction between the H-bar cue and the horizontal one-dimensional correlation structure of the 1D-correlated images.

Fraction Correct

SAME
V-Bar
H-Bar
Frame

LUM   EVEN   1D-corr   SYM

SAME

V-Bar

H-Bar

Frame

SUMMARY & CONCLUSIONS

➤ **Segmentation effects are graded. Even for image statistics that support segmentation, segmentation cues (GRAY bkgd, Frame cue) further enhance performance.**

➤ **Symmetry, while visually salient, does not support segmentation by itself.**

➤ **Detection of both local and long-range image statistics is unaffected by positional uncertainty.**