TEMPORAL STABILITY OF IMAGE STATISTICS IN VISUAL WORKING MEMORY

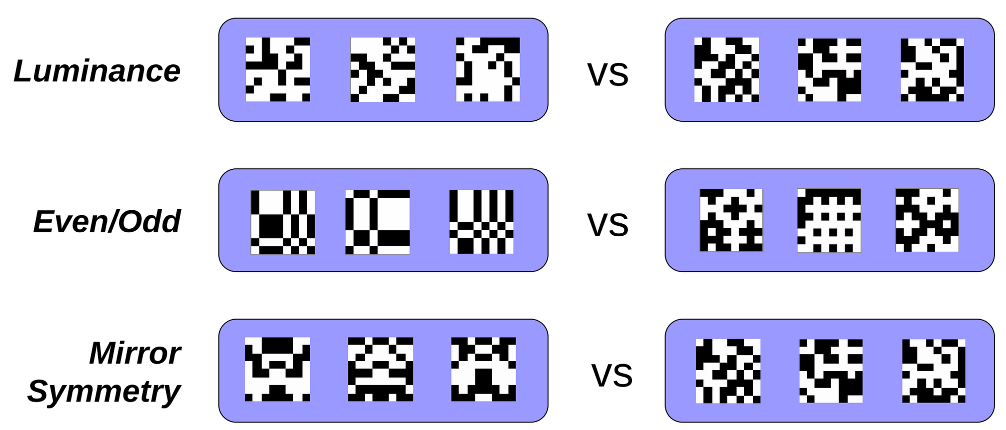
Mary M. Conte and Jonathan D. Victor

Department of Neurology and Neuroscience, Weill Medical College of Cornell University, New York, NY 10021

INTRODUCTION

Images can be represented in visual working memory not only on a pixel-by-pixel basis, but also in a more abstract way, in terms of their statistical structure. We previously showed (ARVO, 2002) that for 1st-order statistics (luminance) and local 4th-order statistics (higher-order structure), this representation is graded, not categorical. The goal of this study is to examine the timecourse of pixel-by-pixel and statistical representation of images in visual working memory.

3 STIMULUS CLASSES

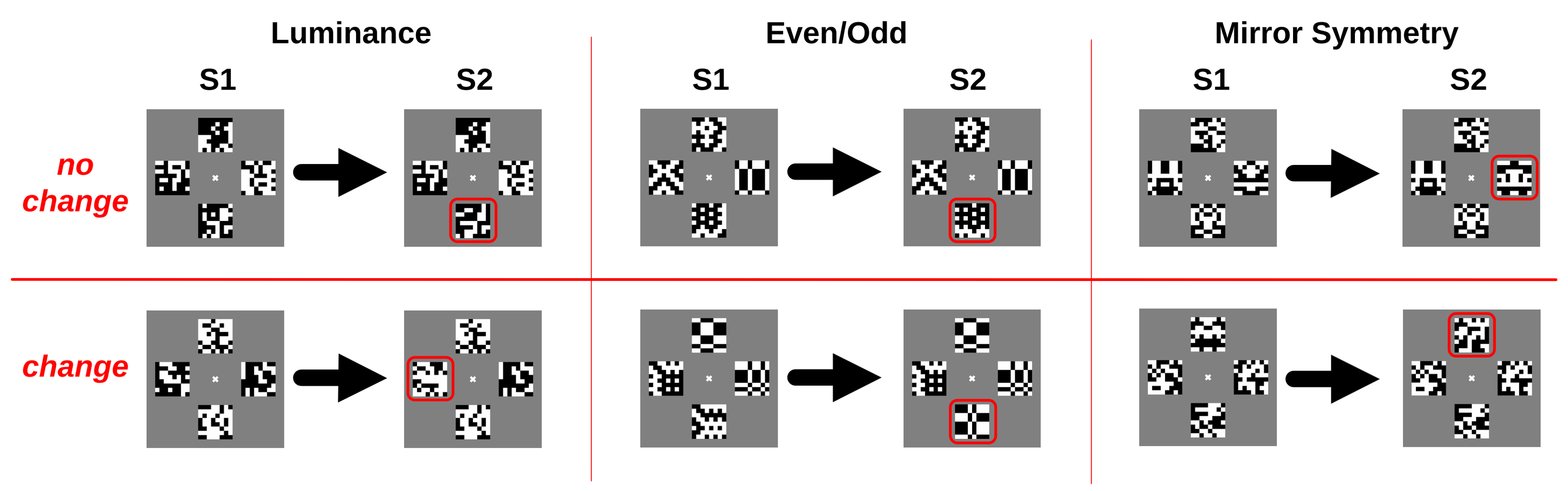


Each stimulus (see six sample trials below) contained arrays drawn from one of the three classes exemplified above. In each class, a single statistical attribute was varied: luminance, local fourth-order correlation (even and odd isodipole textures), and long-range statistics (mirror symmetry). The range of variation of the statistical attribute is indicated by the two extremes paired above.

METHODS

- N = 9 trained observers; corrected to 20/20 VA
- Stimuli consist of four arrays, each subtending 2.7 deg, centered at 4 deg from fixation
- Each array: 8 x 8 checks, check size 20 min, contrast = 1.0
- Binocular viewing at 102.6 cm
- Mean luminance: 47 cd/m^2
- Cambridge Research VSG2/3 system
- 4-AFC paradigm; without feedback
- 1536 trials per subject
- Measured fraction correct (FC) and reaction times (RT)
- Full-factorial ANOVA

2 CHANGES IN STATISTICAL STRUCTURE

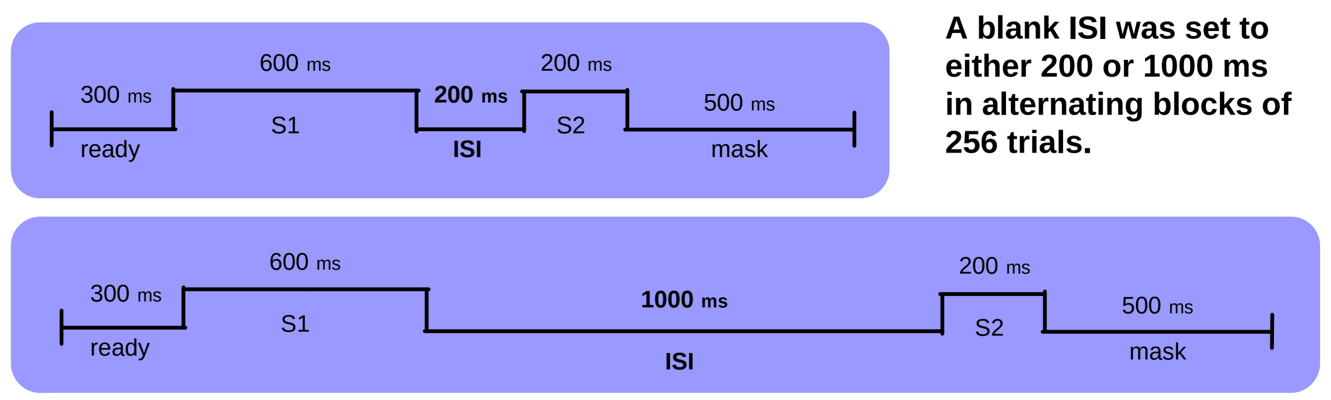


TASK: Which one of the four arrays has changed?

In S1, four 8x8 arrays of black and white checks were presented; in S2, one of the arrays was altered by changing the luminance of 16 checks. Temporal sequences of trials are shown below.

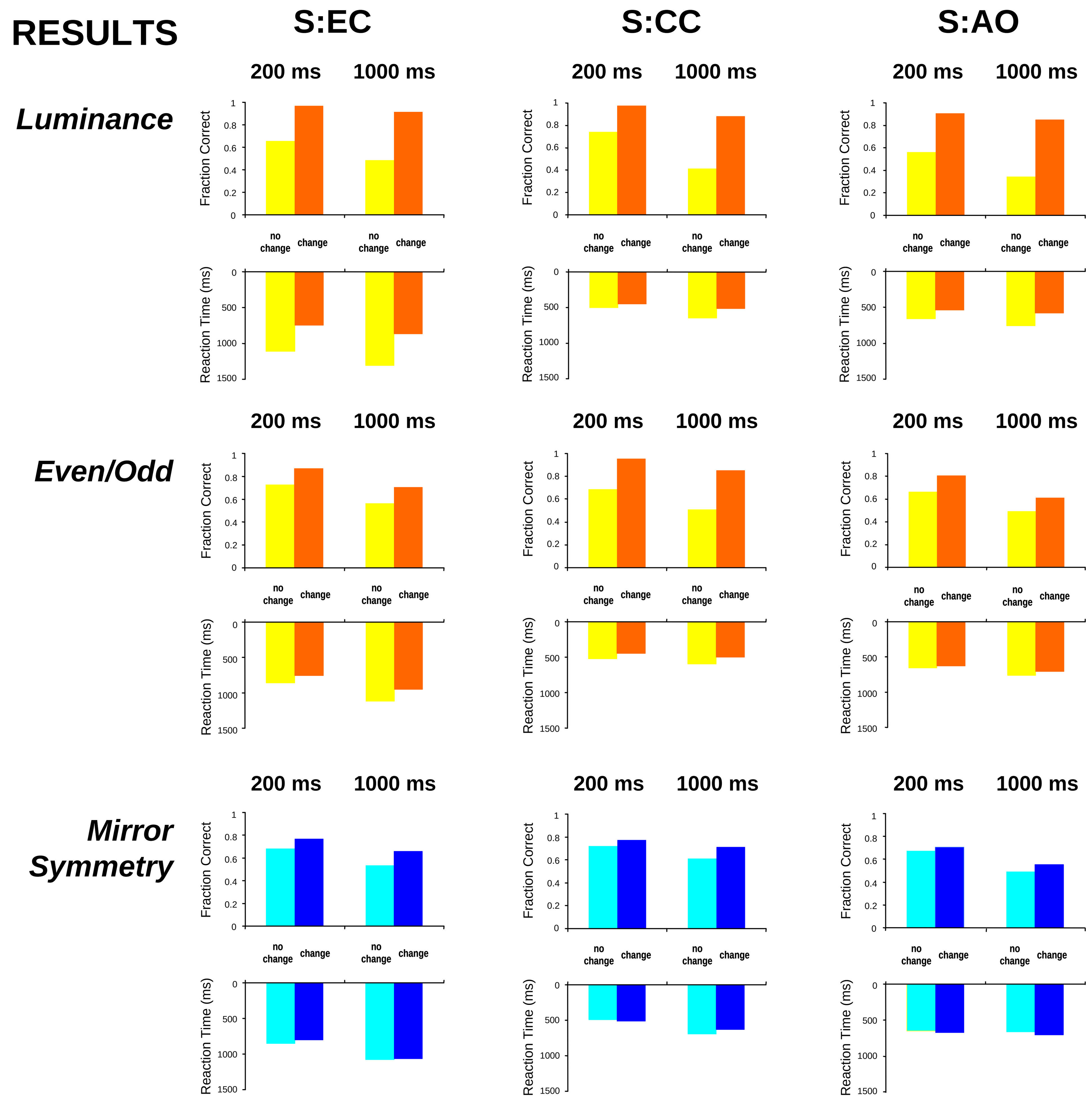
In the *no change* condition, the statistics of the target in S2 matched the statistics of the array in S1 that it replaced (e.g., dark to dark, odd to odd, symmetric to symmetric). In the *change* condition, the statistics of the target in S2 differed from those of the array in S1 (e.g., dark to light, odd to even, symmetric to random).

2 TIMECOURSES



A blank ISI was set to either 200 or 1000 ms in alternating blocks of 256 trials.

RESULTS



MAIN EFFECTS

STATISTICAL CHANGE

The largest main effect was that of a change in statistical structure. Fraction correct in the *change* condition was 0.20 greater than in the *no change* condition, and reaction time decreased by 168 ms.

TIMECOURSE

Fraction correct was greater for the 200 ms ISI condition than for the 1000 ms ISI condition by 0.10 and reaction time decreased by 78 ms.

STIMULUS CLASS

Fraction correct for *Luminance* and *Even/Odd* conditions were not significantly different from each other (see table below), but both were greater than for the *Mirror Symmetry* condition by 0.06. Similarly, reaction time for *Luminance* and *Even/Odd* conditions were not significantly different, but were shorter than for *Mirror Symmetry* by 50 ms.

2-WAY INTERACTIONS

STIMULUS CLASS x STATISTICAL CHANGE

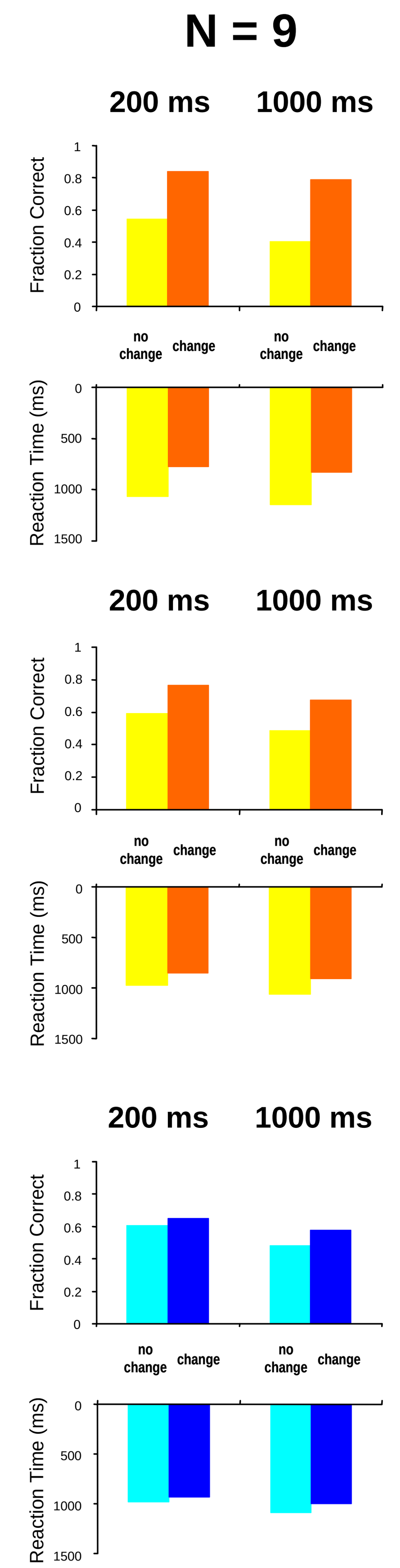
This interaction was significant both for fraction correct and reaction time. The effect of a statistical change was largest for *Luminance*, next-largest for *Even/Odd*, and minimal for *Mirror Symmetry*.

TIMECOURSE x STATISTICAL CHANGE

This interaction was significant both for fraction correct and reaction time. The effect of a statistical change was larger for the longer ISI.

STIMULUS CLASS x TIMECOURSE

This interaction was not significant for either fraction correct or reaction time, indicating that the deterioration in performance with time was similar across the 3 stimulus classes.



ANOVA SUMMARY

**p < .01; ***p < .0001; NS = not significant	All Data FC	All Data RT	Luminance & E/O classes only FC	Luminance & E/O classes only RT
MAIN EFFECTS				
Statistical Change	***	***	***	***
ISI Time	***	***	***	***
Stimulus Class	***	***	NS	NS
2-way INTERACTIONS				
Stimulus Class x Statistical Change	***	***	***	***
ISI Time x Statistical Change	**	.03	***	NS
Stimulus Class x ISI Time	NS	NS	NS	NS
3-way INTERACTION				
Stimulus Class x ISI Time x Statistical Change	NS	NS	.03	NS

Intersubject variability for mean fraction correct was large (range: 0.46 - 0.74; the 9 subjects formed 5 significantly different subsets), and even larger for reaction time (range: 543 - 1431 ms; 7 significantly different subsets). Nevertheless, strong interactions of the factors of interest were present across subjects.

Each of the main effects described above was significant at p < 0.0001, for both fraction correct and reaction time. However, the stimulus class effect was entirely due to the difference between *Mirror Symmetry* and the other two classes, as is seen by the loss of significance when the *Mirror Symmetry* class was excluded from the analysis.

With the *Mirror Symmetry* data excluded, there is a significant three-way interaction between the factors, indicating that the ISI Time x Statistical Change interaction is significantly different between *Luminance* and *Even/Odd*. This likely reflects a difference in stability of these statistics in memory. Our previous work (VSS, 2002) has shown that 1st and 4th-order statistics are readily encoded within 100 ms. However, symmetry is not readily encoded within 100 ms. Thus, the interaction of ISI Time x Statistical Change for *Mirror Symmetry* likely reflects in part the dynamics of encoding, not memory.

CONCLUSIONS

- **A change in image statistics leads to a greater improvement in performance for the longer retention interval (1000 ms), than for the shorter retention interval (200 ms). Thus, memory for image statistics is more stable than memory for individual pixel values.**
- **All image statistics studied played a demonstrable role at the longer retention interval. The largest role was played by luminance statistics, and the next-largest role was played by local fourth-order statistics.**

Supported by NIH EY7977