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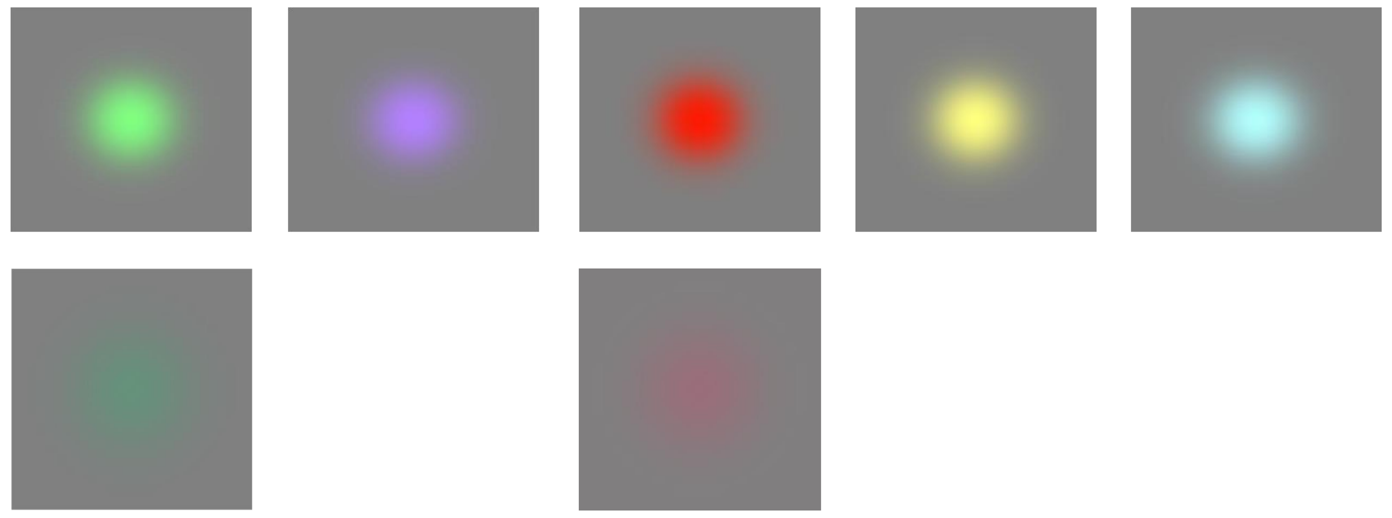
Asymmetric Color Matches Compared to Six Mechanism Chromatic Detection Model

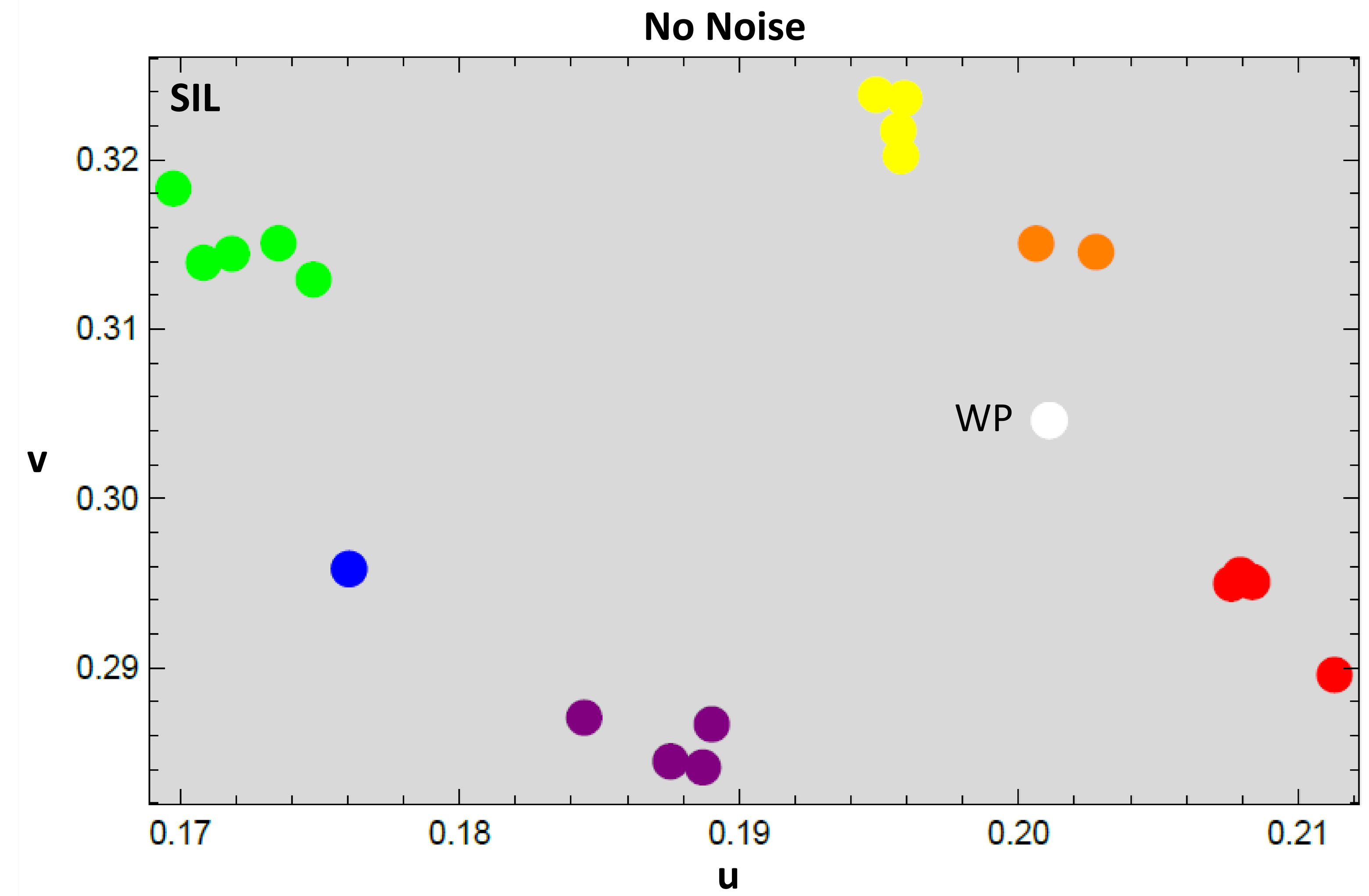
Abstract

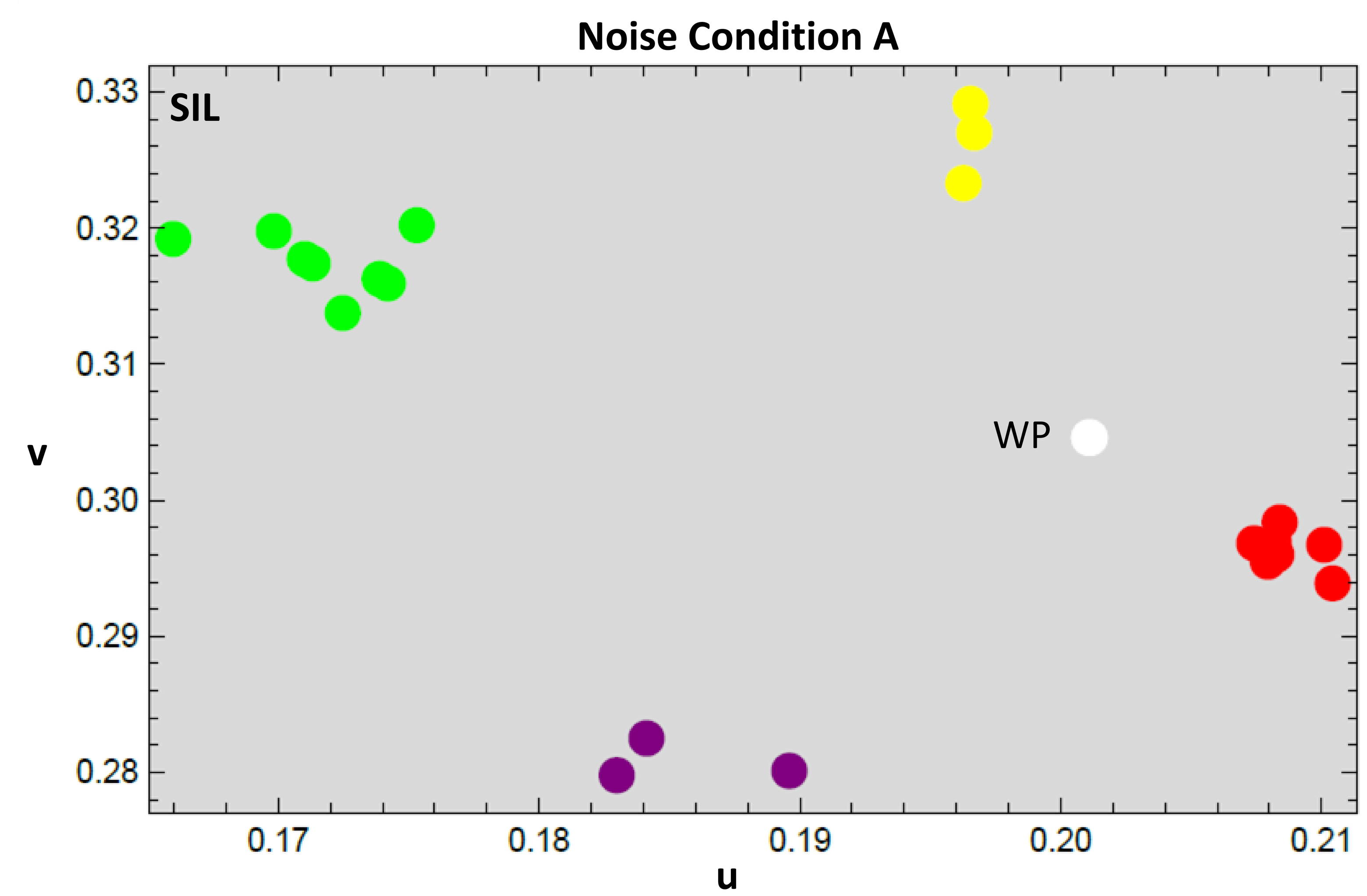
Human color vision is a vital aspect of our perception of the world. We rely on color perception on a day-to-day basis, ranging from object discrimination and face recognition to the detection and determination of whether food is spoiled. Color vision is caused by the differential activation of three cone photoreceptors, each of which is sensitive to a distinct range of wavelengths. However, we have the ability to detect and discriminate between a variety of colors much finer than the broad and overlapping wavelengths that activate the cones. One theory posits that numerous neural mechanisms are required. Another theory holds that as few as six such mechanisms are sufficient, and a later recombination of the signals from these mechanisms gives rise to the variety of discriminable colors. In the present study, using barely-detectable chromatic stimuli, we conducted color-matching experiments on human subjects to help us understand the number and the characteristics of these post-receptoral mechanisms. Cluster analysis revealed six unique color categories, which provides further support for a simple six mechanism model. The six mechanism model does an excellent job of accounting for the psychophysical data and helps resolve a current dispute in color vision research on post-receptoral processing.

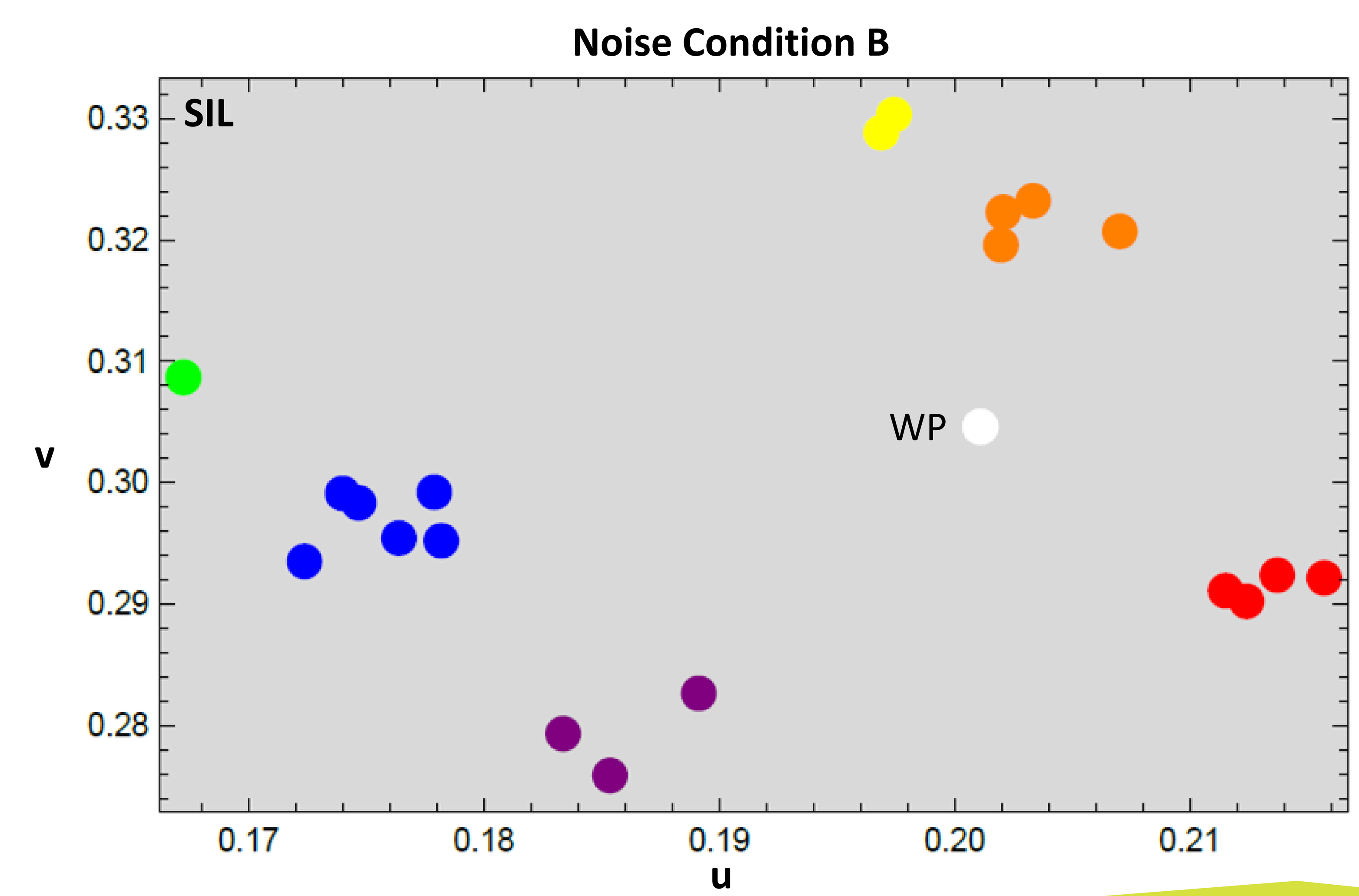
Introduction

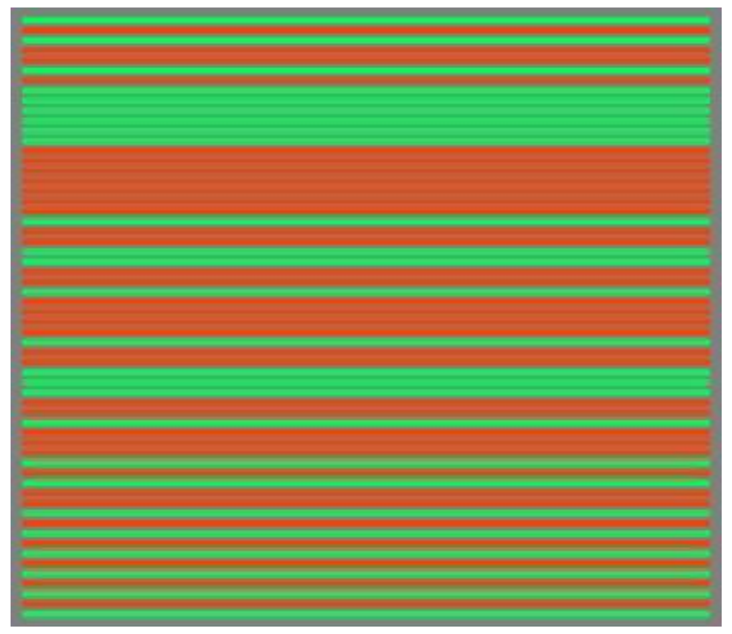
- Color is an interpretation the mind gives to physical stimuli, specifically lights that differ in relative spectral distributions.
- ***Three cone photoreceptors*** in the retina respond to different ranges of wavelengths of light. However, ***we can discriminate between millions of colors.***
- Signals from the photoreceptors recombine in neural circuits called "mechanisms". ***How many mechanisms are responsible for this process? What color does each mechanism detect?***
- Some believe that a simple model with as few as six mechanisms is sufficient (Giulianini & Eskew, 1998). Others believe that a model with as many as 4,096 mechanisms is required (Hansen & Gegenfurtner, 2006). ***Which model is correct?***
- This research, featuring a color matching task, tests the six mechanism model and quantifies the color signaled by each mechanism.

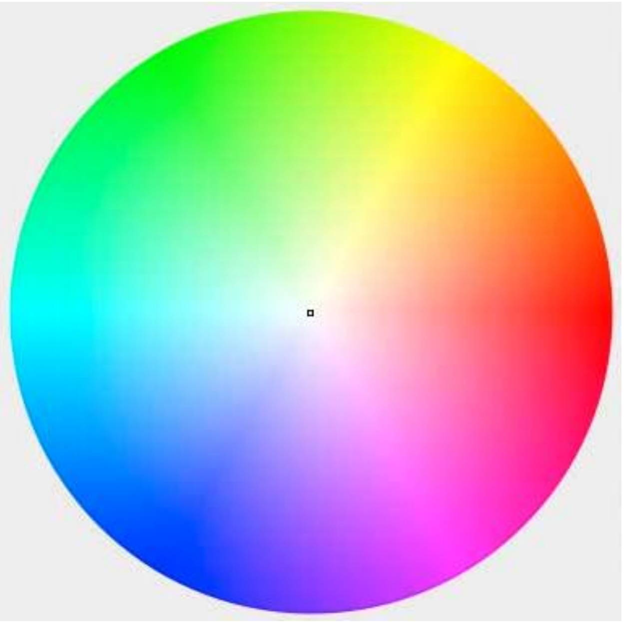












Method

- **Observers:** Three subjects were run in various conditions. Results were similar for all three.
- **Stimuli:** Tests were Gaussian blobs (σ=1°), shown in the bottom left figure. In some conditions, dynamic random patterns (noise) were added to the test to manipulate the sensitivity of mechanisms. Noise consisted of horizontal lines, superimposed on the test, that randomly switched color. An example noise pattern is shown in the left figure above. Noise patterns had different colors in different conditions.
- **Model:** A simple neural network model, consisting of *m* linear combinations of cone signals, was used to fit thresholds in all noise conditions simultaneously. The number of mechanisms was varied; 6, 8, and 16 mechanisms were tested.
- **Color Matching:** Stimuli were presented at their measured threshold levels and subjects matched the test color on an HSV color wheel (above right figure). The colors were transformed to CIE u,v color space.

Results

- Color matches for one subject are shown in the panels at left. Each point is the match to a single test stimulus, colored to indicate the hue of the match. The white point (WP) is the white point of the monitor.
- A K-means cluster analysis of the color matches reveals six clusters, which is consistent with the six mechanism model.

Conclusion

- At threshold, there are at most six clusters of color matches throughout all of the noise conditions.
- These results support the six mechanism theory of color vision.

References: **(1)** Giulianini, F. & Eskew, R. T., Jr. (1998). Chromatic masking in the (ΔL/L, ΔM/M) plane of cone contrast space reveals only two detection mechanisms. *Vision Research, 38*, 3913-3926. **(2)** Hansen, T. & Gegenfurtner, K. (2006). Higher level chromatic mechanisms for image segmentation. *J. Vision, 6*, 239-259.