RESULTS FROM A NOVEL METHOD FOR INVESTIGATING THE NEURAL LOCUS OF CHROMATIC ADAPTATION

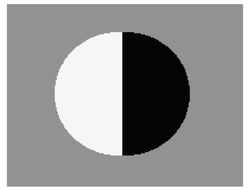
ROBERT ENNIS & QASIM ZAIDI

Graduate Center for Vision Research, State University of New York College of Optometry

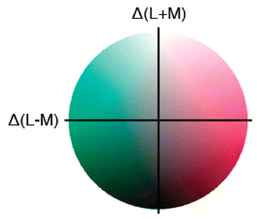
Phenomenonal Observations

- When the color of a disk in a mid-gray surround is modulated through the gray along a single axis, the disk appears mid-gray and continuous with the surround, when the two are physically different. The fields appear different when they are physically equal.
- We use this method to study adaptation to time-varying chromatic stimuli. It can be used to determine the locus of adaptation and the temporal properties of the mediating mechanisms.

Experiment 1 - Tests of identity across cone combinations



- The colors of both halves of a bipartite disk (5°) were controlled independently.
- Each half was modulated at 1/32Hz for half of a cycle.
- The disk was embedded in a surround that was always at mid-gray.

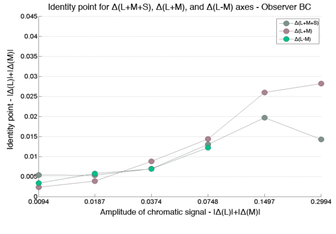


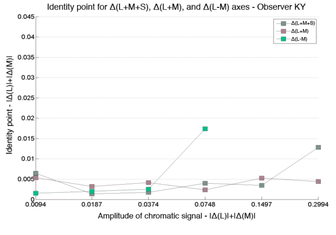
- We modulated the disks along the Δ(L+M+S), Δ(L+M), and Δ(L-M) axes at |(ΔL)|+|(ΔM)| contrasts of 0.0094, 0.0188, 0.0376, and 0.0752. We tested the Δ(L+M+S) and Δ(L+M) axes at two additional contrasts of 0.1504 and 0.3008.
- The color of each half of the disk starts at one of the white dots and proceeds in the direction of the respective arrowhead. The specific arrowhead depends on the axis being tested. The modulation is sinusoidal and ends when the color returns to the white dot.

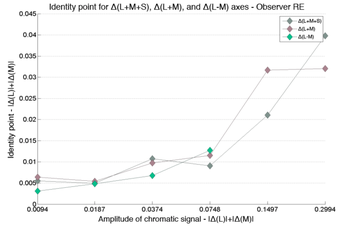
- A 0.67°square containing eight radial mid-gray lines overlays the center of the bipartite disk. Each line within the square can turn black for 100ms, returning to gray at the end.
- We segmented an 800 ms section from the second half of the modulation into eight 100 ms intervals, during which the radial lines are animated like the hand of a clock.

- **Task:** The subject indicates which bar is on the screen when the two halves of the disk appear the same. We adaptively shift the 800 ms section after each trial, so that the observer's response converges to the central interval.

- We use the physical |Δ(L)|+|Δ(M)| contrast at the point of subjective identity of the two halves as the measure of differential adaptation to the two modulations.

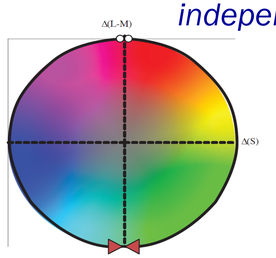






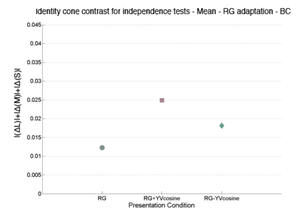
- For three observers, the magnitude of adaptation for modulations along the Δ(L-M) axis was similar to adaptation to Δ(L+M) modulations, indicating that the locus of adaptation was prior to the combination of cone signals.

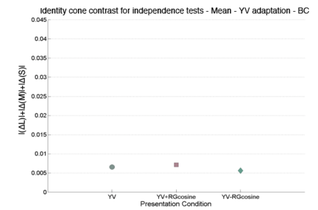
Experiment 2 – Tests of independence

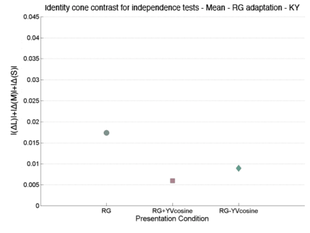


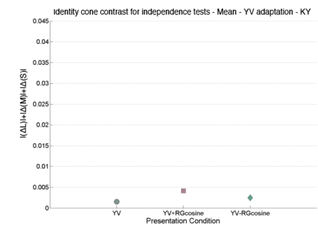
- We test the independence of mechanisms that respond to modulation along the cardinal axes by presenting modulations along a single axis, Δ(L-M) or Δ(S), and combinations of modulations along the Δ(L-M) and Δ(S) axes along the circumference of the color circle (Zaidi & Halevy, 1993, Sun, et. al., 2006)

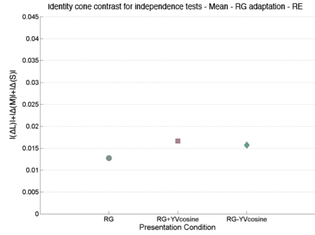
- Every waveform had an amplitude of |Δ(L)|+|Δ(M)|+|Δ(S)| = 0.0752

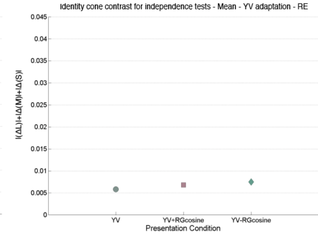




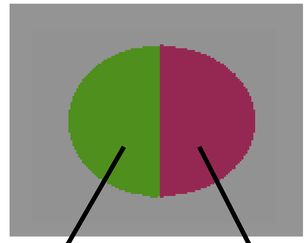


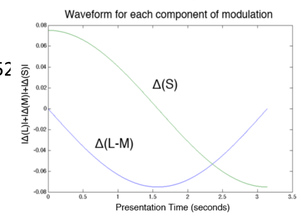


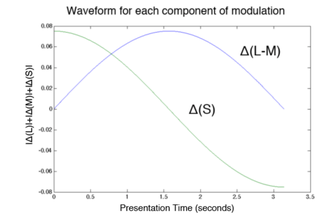




- Adding a cosine modulation along the Δ(S) axis (either positive or negative) to sine modulation along the Δ(L-M) axis does not significantly change the identity point, when compared to sine modulation solely along the Δ(L-M)axis. The same result appears when cosine modulations along the Δ(L-M) axis are added to a sine modulation along the Δ(S) axis.
- Adaptation along the Δ(L-M) and Δ(S) axes is independent







Discussion

- This method has greater efficiency and precision than a reaction time task.
- Williams & MacLeod (1978) showed that strong bleaching fields lead to cone-specific aftereffects. We generalized this to time-varying moderate fields.
- Hartridge (1949) described that the same color sequence presented in two opposite directions appears to contain different colors. At high speeds, this is due to lags in the S-cone system (Lee, et. al., 2009). We show that adaptation will cause the colors to be shifted at slow speeds.
- With this technique, the temporal aspects of the adaptation process can be examined by using more temporal frequencies and sums and differences of frequencies.
- An additional test for the locus of adaptation is to determine if adaptation due to modulations along oblique axes can be predicted from modulations along orthogonal axes.

References

- Hartridge, H. *Colours and how we see them*. London: Bell (1949)
- Lee, R.J., Mollon, J.D., Zaidi Q., & Smithson, H. *Latency characteristics of the short-wavelength-sensitive cones and their associated pathways.* J. of Vision, **9(12):5**, 1-17 (2009).
- Sun, H., Smithson, H., Lee, B.B., & Zaidi, Q. *Specificity of cone inputs to macaque retinal ganglion cells.* J. Neurophysiology, **95**, 837-849 (2006).
- Williams, D. & Macleod, D. *Interchangeable backgrounds for cone afterimages,* Vision Research, **19**, 867-877 (1978)
- Zaidi, Q. & Halevy, D. *Visual Mechanisms that signal the direction of color changes*. Vision Research, **33**, 1037-1051 (1993).
- Hansen, T. & Gegenfurtner, K. *Higher level chromatic mechanisms for image segmentation.* J. of Vision, **6(3):5**, 239-259 (2006).

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