Hue, saturation and brightness scaling of signals from single cones

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The algorithm used by the visual system to extract hue, saturation and brightness from the ambiguous signals generated by cone photoreceptors is unknown. We investigated this computation by stimulating individual cones in human subjects and recording the associated percepts.

An adaptive optics scanning laser ophthalmoscope was used to image and present stimuli to the retina ~1.5° from the fovea. The eye's optical aberrations were measured with a wavefront sensor (940 nm) and corrected with a deformable mirror. Imaging and eye-tracking was performed with 840 nm light. Cones were targeted with spots (543 nm; 500 ms; 0.45 arcmin) that varied in intensity from near- to supra-threshold. Chromatic aberration between the three channels was corrected following Harmening et al. 2012. The background appeared white. The spectral class of targeted cones were identified using densitometry (Sabesan, Hofer, Roorda. 2015). Subjects rated the brightness of each stimulus on a scale from zero (not seen) to five (brightest). Stimuli that received brightness ratings above zero were also rated for hue and saturation (Gordon, Abramov, Chan 1994). The subject indicated the percent of red, green, blue, yellow and white contained in each stimulus using five button presses that summed to 100%.

The majority of cones tested mediated desaturated sensations at all intensities. Only a few cones elicited saturated percepts. L-cones tended to generate red, and to a lesser extent yellow, hue reports. M-cones produced predominantly green reports. Hue was largely independent of stimulus intensity and brightness rating. Brightness ratings were positively correlated with stimulus intensity. In summary, over the range of intensities tested, a single cone produced a consistent hue sensation and relatively fixed saturation, but with brightness roughly proportional to stimulus intensity. This is consistent with the interpretation that for percepts associated with single cone stimulation, hue and saturation are independent of photoreceptor isomerization rate.