Plucking strings and playing chords: percepts elicited from single and multiple cone stimulation

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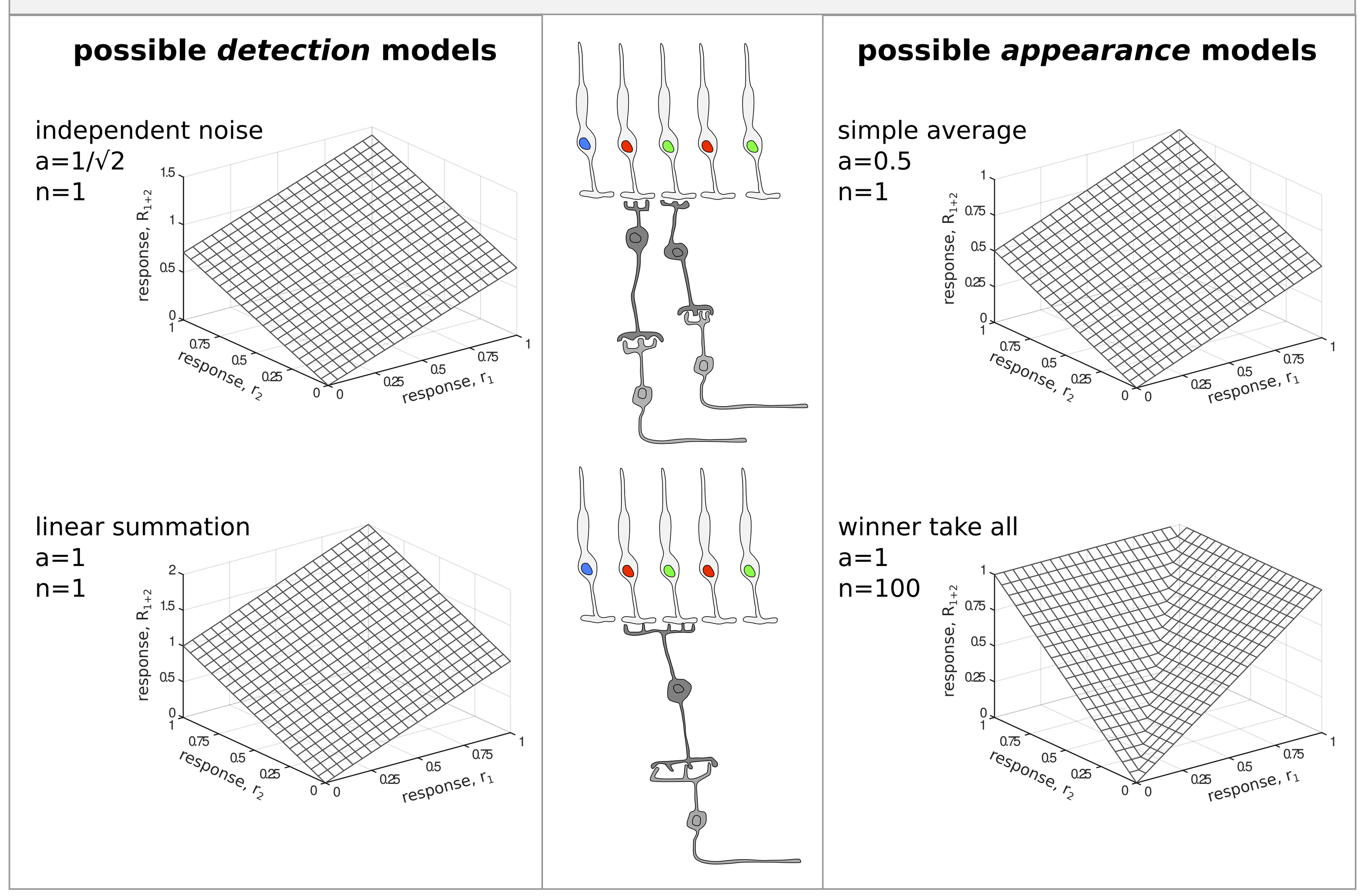
INTRODUCTION

Incoming sensory information is often noisy and ambiguous. One strategy the brain uses to reduce uncertainty is to pool signals from multiple detectors. We studied the rules for combining signals from sensory receptors by targeting individual and pairs of cones with light and recording the associated percept.

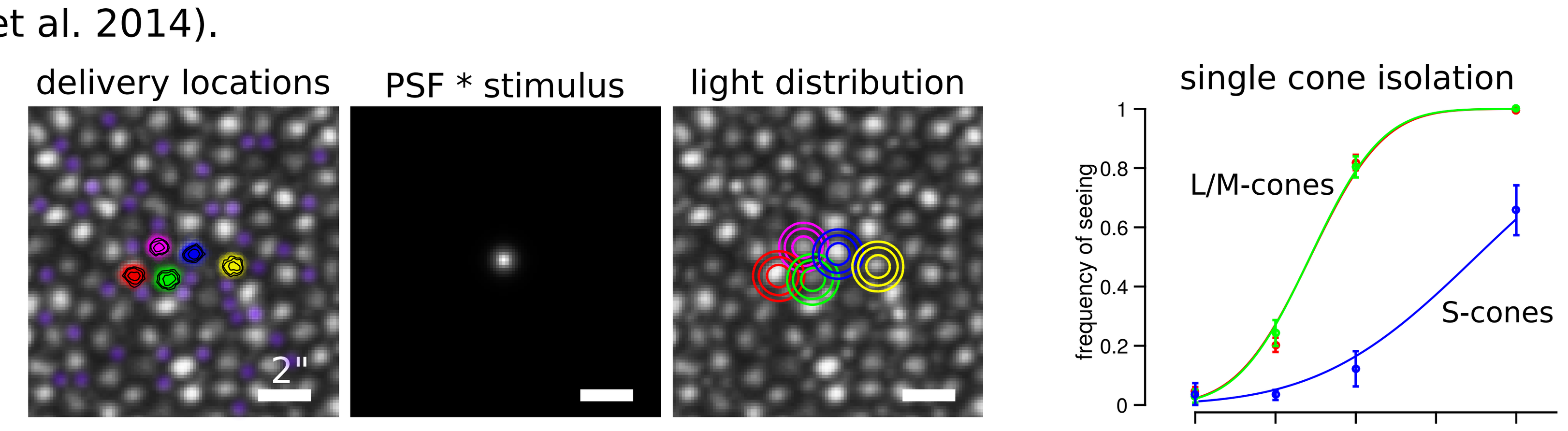
Models of cone summation

$$R_{1+2} = a\,(r_1^{\,n} + r_2^{\,n})^{(1/n)}$$ (Britten & Heuer 1999)



METHODS

Two male and one female subject were enrolled in the study. Cone mosaics (at 1-3 degrees of eccentricity) were imaged and tracked with an adaptive optics scanning laser opthalmoscope (AOSLO). Stimuli (543 nm; 0.35 arcmin; 500 ms) were delivered to cones of interest following established procedures (Harmening et al. 2014).



Targeting light to individual cones. *Left*: Delivery locations of 5 cones. Contours indicate that delivery locations were concentrated at cone centers.Rods were pseudo-colored purple to distinguish them from cones (the larger cells). *Middle*: 3x3 pixel stimulus convolved with a near diffraction limited PSF (6.5 mm pupil with 0.05 diopters of defocus. *Right*: density profile of light capture in each cone computed by summing the PSF * stimulus at each delivery location. Contours encompass 50, 80 and 90% of delivered light. Scale bar = 2 arcmin.

Procedure:

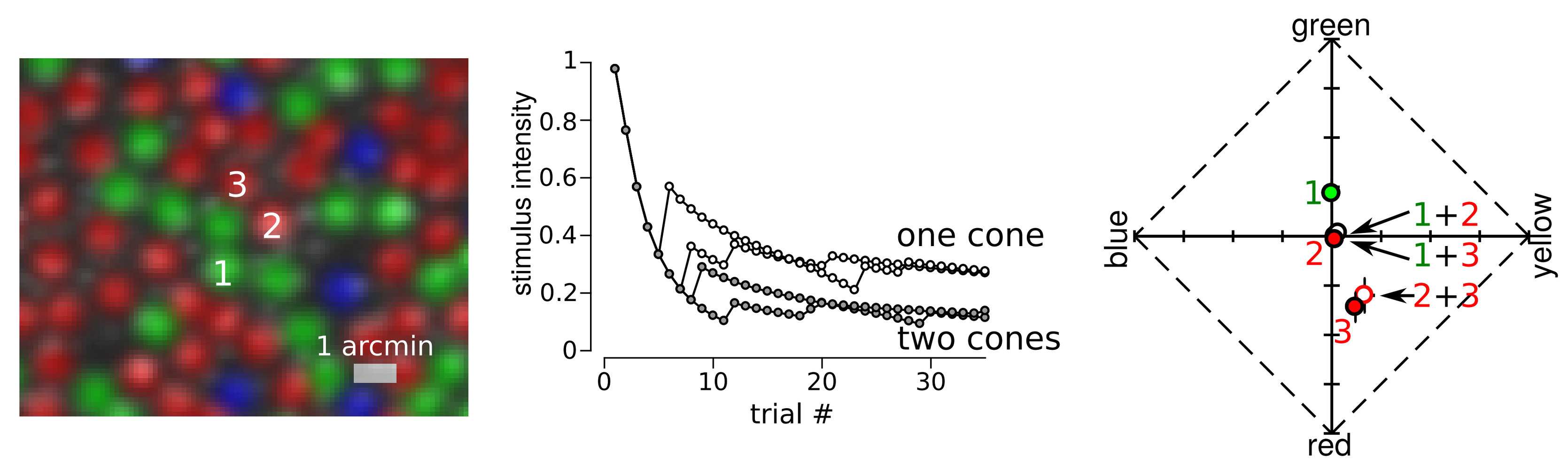
1. Thresholds for detecting 85% of flashes were found with an adaptive staircase procedure for both one- and two-cone conditions.

2. Appearance of flashes were recorded at the measured detection threshold. Subjects indicated the appearance of each stimulus with a hue and saturation scaling procedure (Gordon et al. 1994).

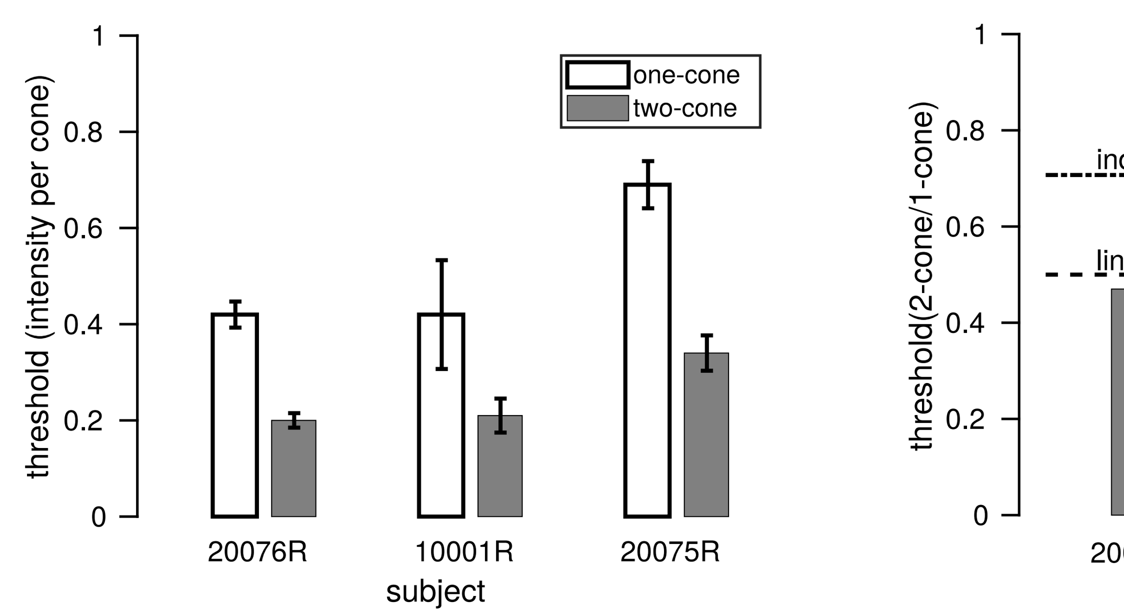
During each session groups of three cones were targeted both individually and in pairs; trials were randomly interleaved. The background in both experiments was a low photopic (~40 cd/m^2) white. Separately, cone mosaics were classified with AOSLO densitometry (Sabesan et al. 2015).

RESULTS

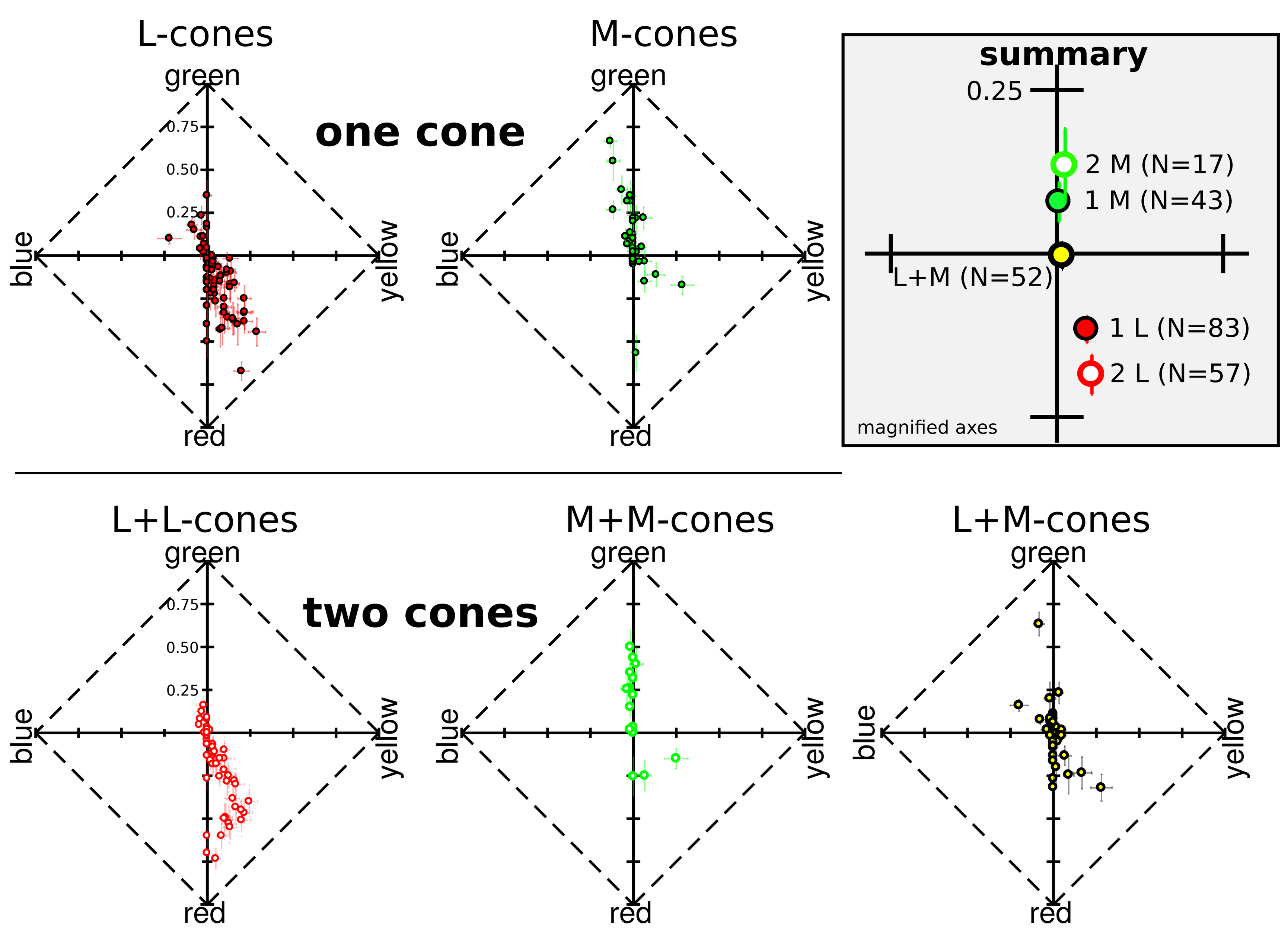
1. Example session: detection and appearance of one and two-point spots.



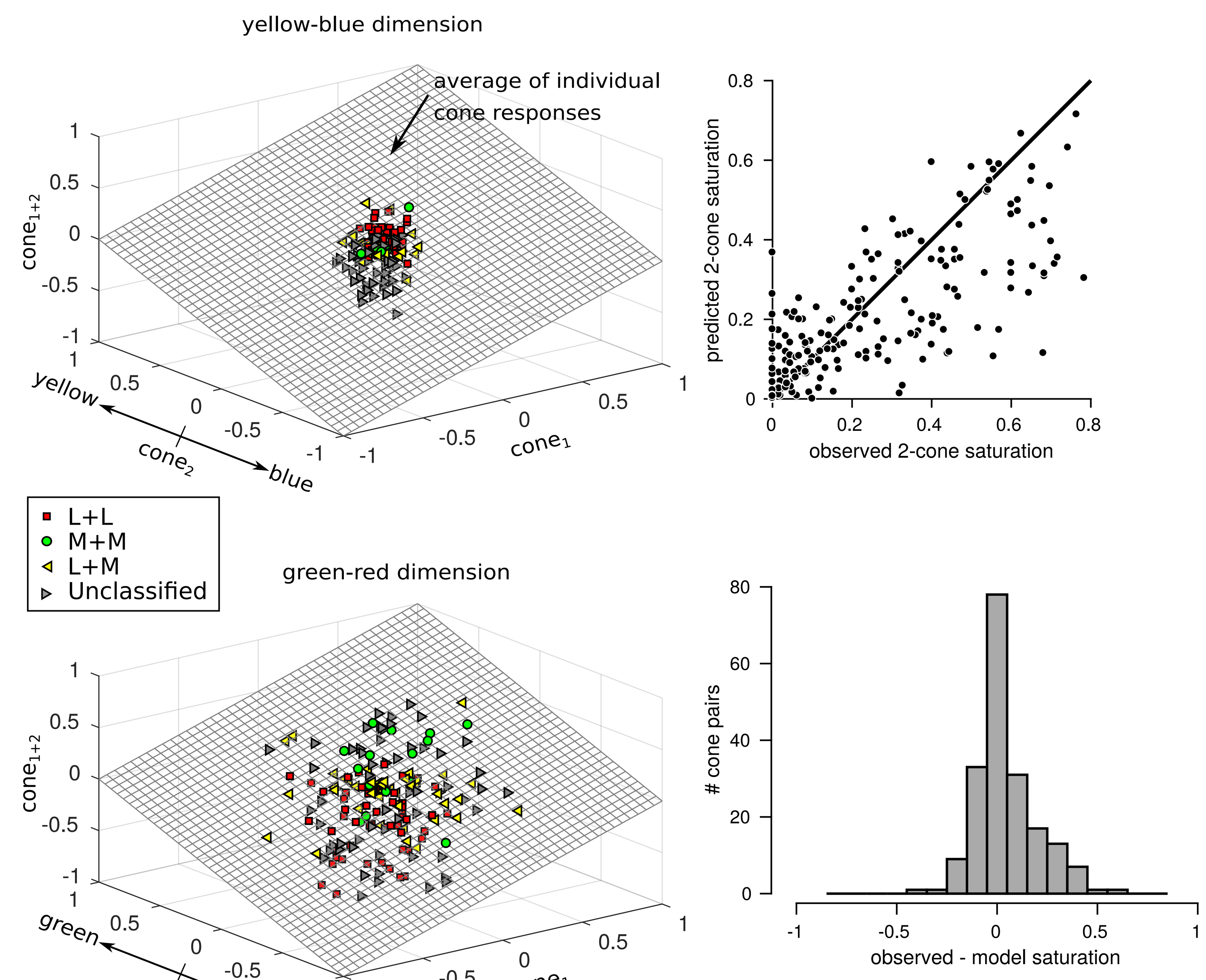
2. Detection of 2-point stimuli was predicted by a linear summation model



3. Appearance judgments were predicted by cone type targeted



4. Simple average predicts hue and saturation of two-point stimuli. However, two-point stimuli were slightly more saturated than predicted by a simple average.



t_{192}=3.91, p=0.0001

Model	Scale (a)	Exponent (n)	Variance (%)
simple average	0.5	1	73
winner-take-all	1	100	38
scaled linear summation	Free: 0.56±0.17	1	73
best-fit scaled power-law	Free: 0.47±0.29	Free: 0.75±0.53	74

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CONCLUSIONS

Two-cone detection thresholds followed the expectations of a single detector that linearly summed signals from individual cones assuming each cone carried minimal noise. In comparison, two-cone appearance judgments were better predicted by a simple average spatial summation model. Together these observations suggest that the detection and appearance judgments were mediated by different neural pathways; potentially implicating the magno- and parvocellular pathways, respectively.

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