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RESPONSE VARIABILITY OF MARMOSET PARVOCELLULAR NEURONS

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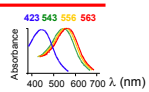
ABSTRACT

The parvocellular division of the primate retinogeniculate pathway includes neurons with a range of sensitivity to luminance and chromatic contrasts. Understanding the functional specialization of these neurons requires a characterization of not only sensitivity, but also response variability. Noise in the phototransduction process and spike generation are likely to have similar effects on response variability across parvocellular neurons, independent of how their cone inputs are combined. However, the intraretinal circuitry that underlies the combination of cone signals may result in differences in response variability across parvocellular neurons with varying degrees of opponency.

We investigated the variability of responses of parvocellular lateral geniculate neurons of genetically-defined dichromatic and trichromatic marmosets, during stimulation by sinusoidal luminance and chromatic gratings. In dichromats and trichromats, for all parvocellular neurons, firing rate variability was approximately consistent with a Poisson process. Consistent with the findings of Croner et al. (1993), variability of the fundamental response component was approximately independent of response amplitude, although there was a modest tendency for larger responses to be more variable. There were also subtle differences in responses driven by chromatic and luminance stimuli. For neurons with pronounced color opponency, chromatic responses were less variable (10-15%, p<0.01) than luminance responses of equal magnitude. Conversely, parvocellular neurons with minimal color opponency showed the opposite tendency. In sum, though noise characteristics of parvocellular neurons are largely independent of the way in which they combine cone signals, the noise characteristics of retinal circuitry may augment specialization of parvocellular neurons to signal luminance or chromatic contrast.

BACKGROUND

MARMOSET CONE PHENOTYPES

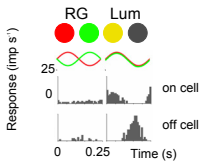


One L/M allele: males and homozygous females
3 kinds of *dichromats*

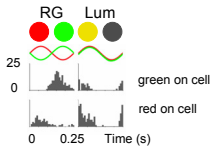
Two L/M alleles: heterozygous females
3 kinds of (potential) *trichromats*

LGN RESPONSE TYPES IN A TRICHROMAT

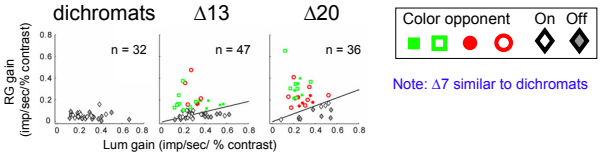
non-opponent



opponent



CONTRAST GAIN: POPULATION DATA



Note: Δ7 similar to dichromats

Chromatic response gain is highest for the Δ20 phenotype.
But signaling capacity depends on response variability, as well as amplitude.

QUESTIONS

- How does response variability of marmoset LGN neurons change as a function of response size?
- Are there systematic differences between dichromats and trichromats, or, between LGN neurons with varying degrees of color opponency?
- At constant response amplitude, does response variability depend on on whether the contrast is chromatic or luminance?

PHYSIOLOGIC METHODS

Extracellular recording in parvocellular LGN of *Callithrix jacchus*, under anesthesia (N_2O, sufentanil) and paralysis

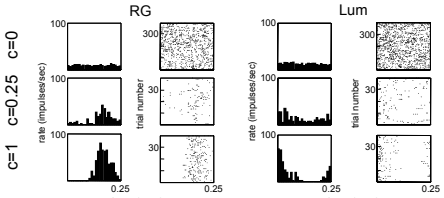
156 neurons in 13 animals: 7 dichromats, 6 (potential) trichromats: one Δ7, three Δ13, two Δ20

Genotyping of opsins: PCR and endonuclease digests

Visual stimulation:
CRT monitor, 80 Hz, mean luminance 55 cd/m²
isoluminant stimuli determined from genotype and electrophysiologically by R/G ratio minimum
full-field sinusoidal flicker, usually 4 Hz
3.5 sec trials, interleaved with blanks
at least 3 repeats (39 stimulus cycles) per contrast
See Blessing et al. (2004) and Yeh et al. (1995) for further details.

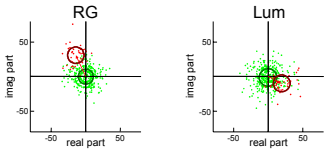
ANALYSIS

HISTOGRAMS AND RASTERS

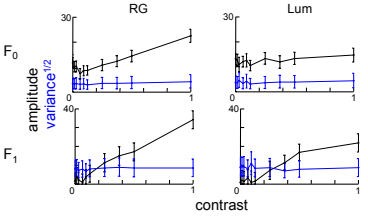


Responses were collected for each of 10 nonzero contrasts and blank (c=0).

RESPONSE AMPLITUDE AND VARIABILITY VS. CONTRAST



The response to each stimulus cycle was Fourier analyzed (only **c=0** and **c=1** are shown here). The response amplitude is the vector mean of the cycle-by-cycle components (arrows). The response variance is the average squared deviation of each trial's response from the vector mean. Radii of the circles indicate variance$^{1/2}$.

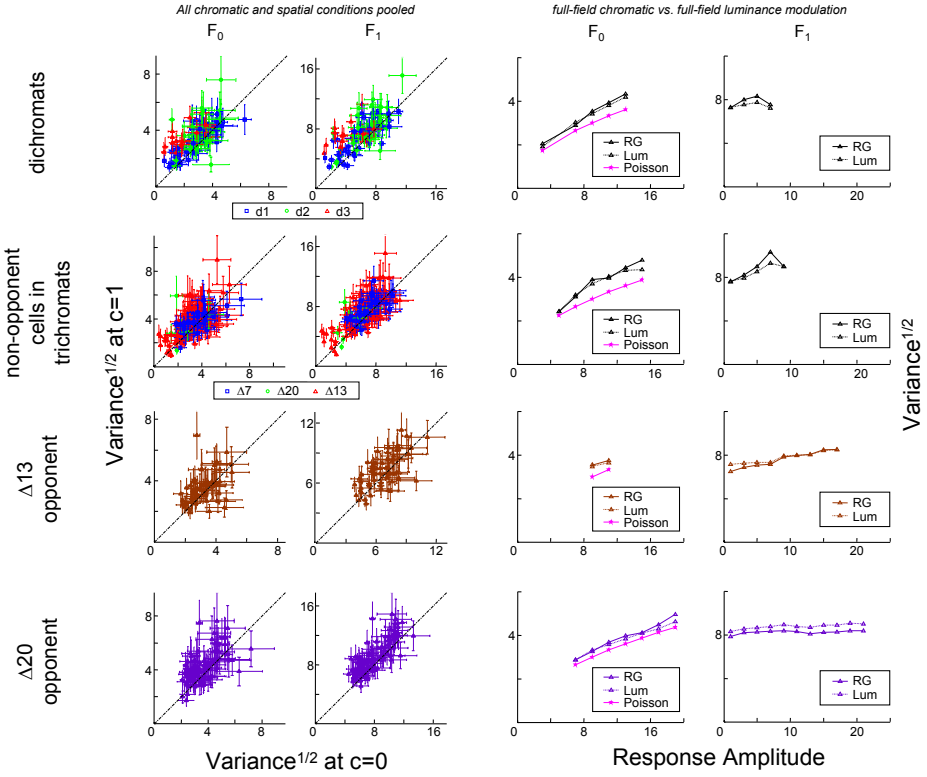


Confidence limits were determined by T^2_{circ} (response amplitude) and F-ratio (variance). For each harmonic (F_0, F_1, F_2, F_{20}) and chromatic condition (RG, Lum), the observed variance vs. response amplitude relationship was fit by an empirical relationship $V(R)=A+BR^9+CR^{2g}$. Forms with fewer parameters, such as $V(R)=A+BR$ or $V(R)=BR^9$, were used if they provided an equally adequate fit, as determined by χ^2. Note that the Poisson prediction for F_0 is $V(R)=R$ and for F_1 is $V(R)=A$ (in the absence of response truncation).

RESULTS

Responses to high contrast stimuli show greater variability than responses to low (or zero) contrast stimuli. This behavior is common to all opponent and non-opponent P-cells.

In color-opponent P-cells in Δ20 trichromats, variability of the fundamental (F_1) response elicited by a chromatic stimulus is lower than the variability of the F_1 response elicited by a luminance stimulus (lower panel). Non-opponent P-cells in dichromats and trichromats have the opposite tendency (upper two panels).



SUMMARY

Consistent with the results of Croner et al. (1993) in the macaque and Kremers et al. (2001) in the marmoset, response variability is largely independent of response amplitude. However, variability does increase somewhat (typically 30%) as response amplitude increases.

The variance vs. amplitude relationship is slightly supra-Poisson (consistent with burstiness). It is similar in dichromat and trichromats, and in cells with minimal or pronounced color opponency.

In cells with pronounced color opponency, chromatic responses were less variable (10-15%, p<0.01) than luminance responses of equal magnitude. Cells with minimal color opponency showed the opposite tendency. These characteristics, which likely result from intraretinal interactions, may augment specialization of parvocellular neurons to signal luminance or chromatic contrast.

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