

Afterimages and Multiplexing

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There is much current interest in the functions of parallel pathways¹ in vision and, in particular, the question of where and how the opponent-color and luminance signals are formed.² According to several lines of evidence, chromatic and achromatic signals both share a common pathway from the retina to the brain; namely, the "sustained" or parvocellular pathway.³ Our recent results⁴ imply that the same multiplexing arrangement also holds for chromatic and achromatic afterimages, surely the most "sustained" phenomena in normal vision.

Using a computer-controlled, contrast-cancellation technique⁴ and image stabilization,⁵ we obtained chromatic (red/green) and achromatic negative afterimages of sine-wave gratings. These grating afterimages were well behaved in every respect; linear in contrast response from 10-90% stimulus contrast, flat and low-pass in spatial frequency response, and exponential in both build-up and decay, with (1/e) time-constants approaching 5 sec in all cases.

On these chromatic and achromatic afterimages, we superimposed 17-msec test flashes of chromatic and achromatic gratings, spatially in-phase and out-of-phase with the afterimages. We measured the flash threshold contrast for all conditions, including a control condition with no afterimage present. Typical results for those 12 permutations are shown in the figure. The adjacent pairs of bars indicate that spatial phase has no significant effect for these short flashes.

The most remarkable results are that (a) neither the chromatic nor the achromatic afterimage has any significant effect on the achromatic grating flash threshold, and (b) both types of afterimages strongly elevate the chromatic grating flash threshold. (Thus, achromatic flashes are useless for studying the spatial or temporal properties of afterimages, while red-green isoluminant grating flashes can be used to measure either type of afterimage.) Three subjects gave very similar results. Because our afterimages are so well-behaved as functions of spatial frequency, time, and contrast, we infer that these results represent a wide range of parameters surrounding the values used in the figure.

The simplest explanation for this behavior involves the parvocellular and magnocellular ("sustained" and "transient") parallel pathways in the retina, lateral geniculate and striate cortex, and the linking hypothesis that color-opponent and achromatic signals share the parvocellular pathways. The threshold of the isoluminant chromatic probe is presumably controlled by the parvocellular system, because the magnocellular system has little or no response to isoluminant stimuli. Since both chromatic and achromatic afterimages elevate this threshold, both must affect the parvocellular pathways.

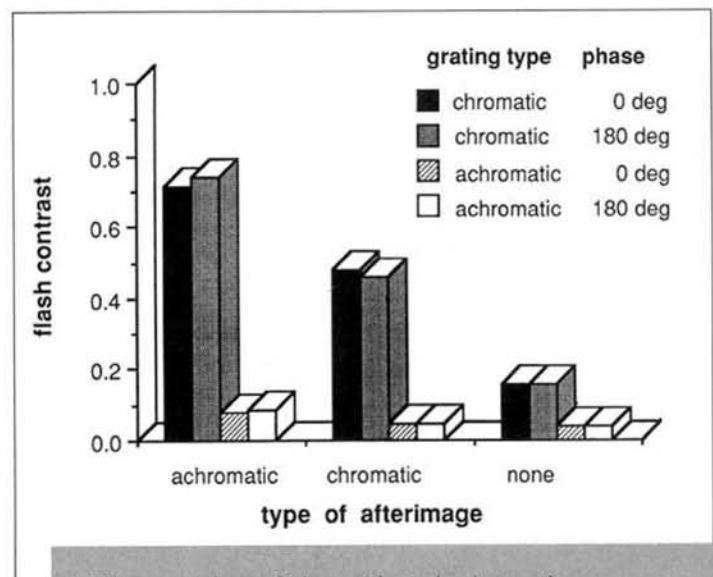
The parvocellular system may also respond to the achromatic probe flash. But at the low spatial frequency (0.75 cycles/degree) used in the figure, the response of the

magnocellular system is much greater to a short flash of luminous contrast; therefore the magnocellular response controls the threshold for the achromatic probe. But neither chromatic nor achromatic afterimages elevate that threshold, implying that neither type of afterimage involves the magnocellular pathways.

In addition to providing a novel type of support for the multiplexing model, our results suggest that precisely controlled negative afterimages may provide a powerful tool for other psychophysiological studies of the visual process.

REFERENCES

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All permutations of chromatic and achromatic, flashed-grating contrast thresholds, measured on chromatic and achromatic afterimages 2 sec after offset of 90%-contrast, inducing stimuli. Both afterimages elevate the chromatic threshold, but neither afterimage has a significant effect on the achromatic threshold.