

Vision works by concatenating factors of change

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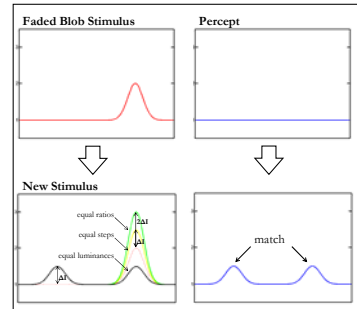
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PROBLEM

As a result of the roughly reciprocal sensitivity regulation expressed in Weber's Law, retinal signals represent not luminance but contrast, or factors of change in luminance. How are brightness and color resurrected from these retinal contrast signals?

(1) Fade and Flash Procedure

We make two backgrounds of different luminance subjectively identical by allowing a Gaussian adapting blob to fade completely under several seconds of steady fixation, until it matches a uniform field. Then we revive the perception of the blob by abruptly incrementing or decrementing its intensity. At the same time, we present an increment or decrement blob in the uniform region. We were able to adjust the magnitude of the change in one blob until the blobs looked nearly the same.

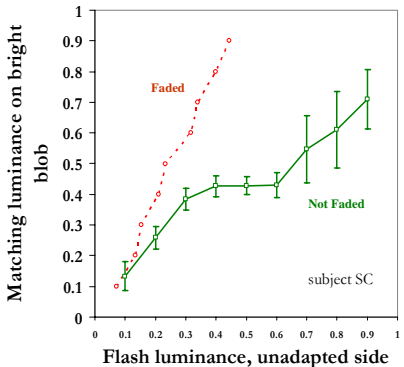
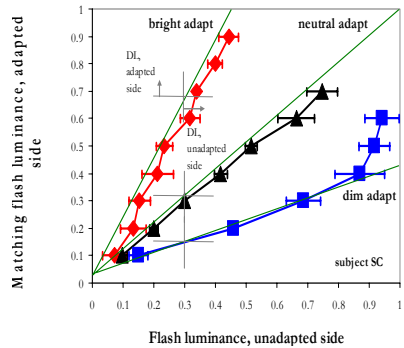
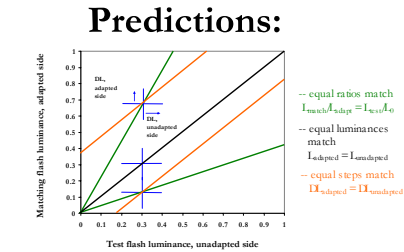


(1a) Matches with complete fading of blob before transition to new stimulus.

Red curve, bright blob, initially twice background luminance.
Blue curve, dark blob, initially half background luminance.
Black curve, no-blob control. Crosses, Initial luminances for center of blob (ordinate) and for surround (abscissa)
Result: Equal *ratios* match, as expected if brightness gain is reciprocally related to the luminance of faded blob.

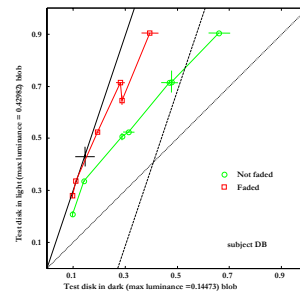
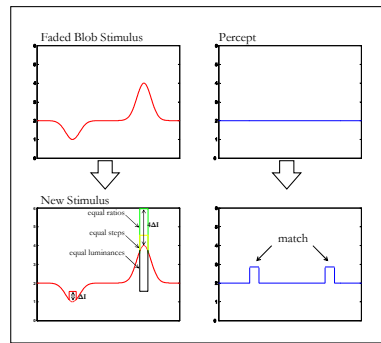
(1b) Matches made while the adapting blob remains unfaded.

Green curve, adapting blob is abruptly introduced into a previously uniform field, with new stimulus following only 750ms later. Here equal *luminances* match; brightness gains are now nearly equal, despite unequal retinal sensitivities.
Red curve, fully faded data from 1a for comparison



(2) Flashed Discs embedded in Faded Blobs

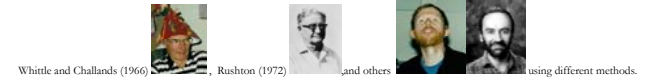
A light and dark blob were presented and allowed to fade until the field appeared uniform. Then, small test disks were briefly presented in the center of the faded luminance blobs. We were able to adjust the magnitude of the test disks until they looked nearly the same.



Red curve, matches after blob has fully faded. Again, equal *ratios* match. Brightness gain is thus reciprocally related to the luminance of the faded background, as in (1a).
Green curve: before fading, the brightness gains are more equal, as shown by the less steep slope of the green matching locus: here again, as in (1b), the brightness contribution of the unfaded background is not additive, but multiplicative. (The additive prediction is the dashed line, which has a change in intercept but none in slope.)

SUMMARY and Gratuitous Remarks

If two blobs with peak luminances I_1 and I_2 are allowed to fade completely, then suddenly changed, by the same factor, to new unequal luminances $I_2 = kI_1$ and $I_2 = kI_1$, the changed regions reappear but (within limits) remain matched. The ratio of the *brightness gains* in the two regions could be defined as $(I_2/I_1)/(I_2/I_1)$ for values of luminance that preserve the match. The gain ratio is roughly $(k-1)I_1/(k-1)I_1 = I_1/I_1$, reflecting the retina's reciprocal sensitivity adjustment in response to the initial luminances of the faded blobs. This supports previous results of



But, if the new intensities are introduced early during the fading of the blob pair when the two contexts are still visibly different, the two brightness gains are more nearly equal, even though threshold sensitivities have by then already approached their steady-state reciprocal values. The very different behavior in the faded and unfaded conditions is understandable if the subjectively perceived baseline of local brightness, generated by the spatial and temporal context combines multiplicatively, not additively, with the reciprocally scaled retinal signal in the revision of our perception.

Our results provide experimental support for Land's proposal for achieving nearly veridical perception despite reciprocal adjustments of retinal sensitivity. The brain can make appropriate use of retinal signals that specify factors of change only if it considers what the factor of change is applied to; to do this it must effectively concatenate the retinal factor-of-change signals relevant to the background with those that differentiate between the background and the test patch, either by suitable combination of signals in a bottom-up architecture, or else by using the retinal input merely to test hypotheses about brightness and color of elements of the scene.

Thus strong illusions of brightness and color contrast occur when the perception of spatial or temporal context is disturbed by blur or fading. Below, the two rings are similar but are seen differently because vision fails to take full account of the difference between their spatial backgrounds, that is signaled only by a blurred contour. And blobs like those below can likewise generate strong afterimages after fading, an observation related to our 1st experiment.

References

Land, E.H. (1964). The retina. *Scientific American*, 52, 247-264
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 Whittle, P., and Challands, P.D.C. (1969) The effect of background luminance on the brightness of flashes *Vision. Res.* 9, 1095-110
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Postscripts

