Visual Adaptation to Gradual Change of Intensity

Abstract. *The eye can adapt to the rate of change of brightness. After exposure of the eye to a light that grows gradually brighter, a steady light appears to grow gradually dimmer, and vice versa. A field containing shading gives larger aftereffects than a spatially uniform field.*

In the well-known processes of light and dark adaptation, the eye adjusts its sensitivity to the prevailing intensity of illumination. In a new effect reported here, the eye adapts, not to the intensity, but to the rate of change of illumination.

The eye was first adapted by fixating a light which grew gradually brighter. Then the light was switched to a steady intensity, and an aftereffect was seen that appeared to grow gradually dimmer. Conversely, after the eye was adapted to a light that grew gradually dimmer, a light of steady intensity appeared to grow gradually brighter. The effect was confined to the stimulated areas of the retina. The aftereffect from a 30-second adaptation lasted from 1 to 10 seconds.

In practice, it is convenient to vary the intensity in an oscillating, sawtooth wave, so that it brightens or dims repetitively. A single cycle can produce a small aftereffect; many cycles produce a larger one. The brightening or dimming aftereffect is opposite in direction from the slow phase of the sawtooth waveform, and does not itself include any perceived oscillation in brightness (Fig. 1). The effect occurs with white light, and with any visible, monochromatic light. Almost any light source can produce the effect. I used Ferranti R1130B glow modulator neon lamps.

The frequency and intensity of the stimulus, and the area stimulated, are not critical. A cycling rate of 1 cycle/sec and an intensity range of 100 to 1 (2 log units) were about optimum. A pinhole source in a dark room caused a minimum effect in some subjects and no effect in others. The same was true for the entire visual field, secured when half a table tennis ball was fitted over each eye and the subject looked straight into the beam of an intensity-modulated projector. With either the pinhole or the entire visual field, the intensity modulation of the stimulus itself was inconspicuous to the subject.

Different parts of the retina can be differently adapted at the same time. A disc was divided into two halves, and each half was lit uniformly and independently by a separate neon lamp. When the two halves varied in intensity in the same direction (both brightening, or both dimming), but out of phase by any angle, then each half of the retina had an aftereffect in the appropriate direction (both dimming, or both brightening). When the two halves varied in phase, but in opposite directions (left half dimming, right half brightening), then each half had an aftereffect in the appropriate direction (left half brightening, right half dimming).

A checkerboard of 1-inch squares (12 by 12) of Polaroid was fixated through a piece of Polaroid which turned steadily through 90°, then returned sharply to 0°, so that the white squares gradually turned black, and vice versa. The appropriate aftereffects were observed in each square.

Contrast can influence the effect. A square subtending a visual angle of 4° and held at a steady intensity, was centered in a square adapting field subtending a visual angle of 45°. The intensity of this field continually increased, following an oscillating, sawtooth waveform. Owing to the contrast in brightness, the steady central square appeared to be continually dimming, in contrast to the surrounding square. After 30 seconds the intensities of both the central square and the adapting, surrounding area were held steady. The surrounding area now appeared to grow dimmer for 10 to 15 seconds, and the

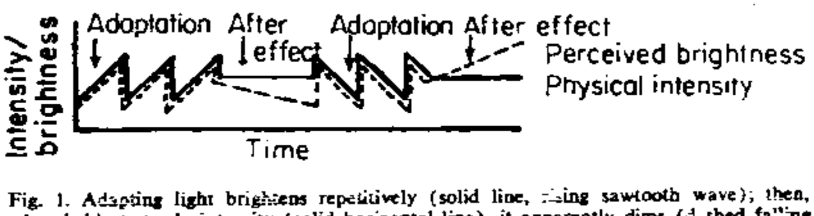

Fig. 1. Adapting light brightens repetitively (solid line, rising sawtooth wave); then, when held at steady intensity (solid horizontal line), it apparently dims (dashed falling line). Or, it dims repetitively (solid line, falling sawtooth wave); then, when it is held steady, it apparently brightens (dashed rising line).

central square appeared to brighten, even though its objective intensity had remained constant throughout the experiment.

Correspondingly, when the area surrounding the square grew continually dimmer during the stimulation period, the steady central square apparently grew brighter. During the aftereffect the surrounding area apparently grew brighter, and the central square apparently grew dimmer.

The aftereffect can be greatly increased by a spatial intensity gradient (shading) across the field. The shading can be either on the oscillating field to which the subject adapts, or on the steady afterfield against which he sees the aftereffect. A square, uniform adapting field, subtending a visual angle of 2°, was repetitively increased in intensity over an intensity range of 100 to 1. The aftereffect (mean of 8 subjects) lasted 5.7 seconds. With a shaded adapting field, the mean aftereffect lasted 6.5 seconds; with a shaded afterfield, 8.4 seconds, and with both adapting and afterfield shaded, 8.6 seconds (Fig. 2). The shaded afterfield made a greater contribution than the shaded adapting field to the aftereffect.

There was apparent movement from the bright edge to the dark edge in a continually brightening, spatially shaded adapting field. During the aftereffect, apparent movement in the opposite direction was seen. These movements correspond to the movement of imaginary "contours of equal brightness" across the field. However, the brightness aftereffect described here is quite distinct from the well-known negative aftereffect of movement (*1*).

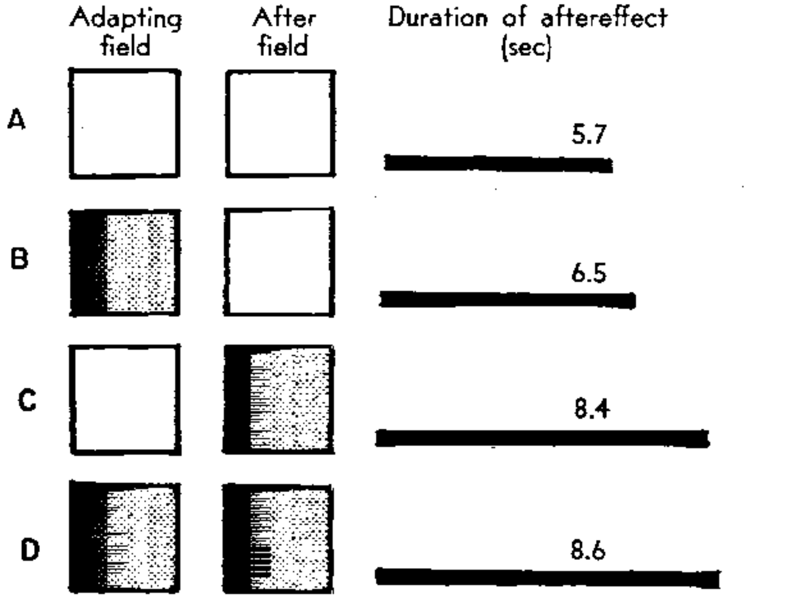

Fig. 2. Spatially uniform adapting field and afterfield produce aftereffect of 5.7 seconds. Shaded adapting field increases aftereffect to 6.5 seconds; shaded afterfield, to 8.4 seconds; shaded adapting field plus shaded afterfield, 8.6 seconds.

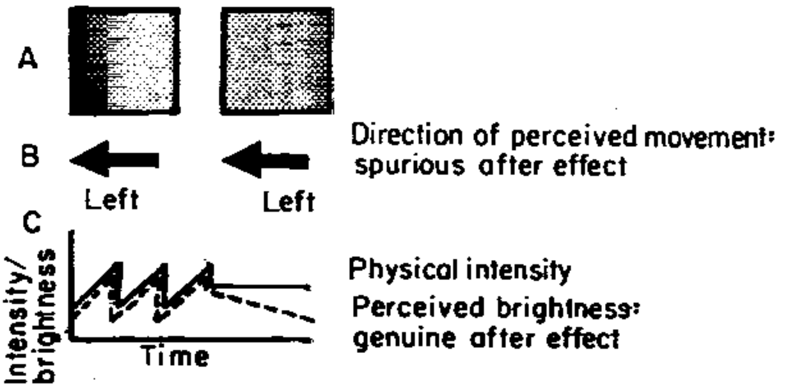

Fig. 3. Brightening adapting field, shaded to be darkest on the left, apparently moves to the left. Steady afterfield, shaded to be darkest on the right, apparently dims and apparently moves to the left. Dimming aftereffect is genuine. But movement aftereffect is an artifact. Genuine aftereffect would apparently move to the right.

A continually brightening, spatially uniform adapting field, containing no directional component, gave a dimming aftereffect on a uniform afterfield. The dimming aftereffect occurred here in the absence of any movement.

A continually brightening adapting field, spatially shaded to be darkest on the left, apparently moved to the left during stimulation (Fig. 3). The gaze was then transferred to a steady afterfield, shaded to be darkest on the right. The reported aftereffect was of dimming plus apparent movement to the left. This was appropriate to the stimulus of changing intensity. The aftereffect appropriate to the stimulus of perceived movement would have been an apparent movement to the left. So the aftereffect reported was one of brightness, not of movement.

The effect is not due to pupillary responses, since it was still observable through an artificial pupil 2 mm in diameter. Also, dimming and brightening effects could be seen simultaneously, side by side, on a checkerboard, but the pupil cannot expand and contract simultaneously.

The effect is probably retinal rather than central. If the left eye viewed a dimming light, and the right eye viewed a brightening light, visually superimposed in a stereoscope, binocular rivalry was reported. Then, if both eyes were closed, or both were open viewing a steady light, no aftereffect was seen. But if one eye was opened, this eye had its own aftereffect, though more feebly than if the other eye had not been stimulated. Also, when one eye was adapted monocularly, little or no aftereffect was observed with the other eye.

The effect appears to be a newly discovered one. It is distinct from the aftereffect of movement. It may represent selective adaptation of "on" and "off" receptors, but its physiological mechanism is not yet known.

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