Negative Afterimage without Prior Positive Image

Abstract. A procedure is described which causes an observer to see a negative afterimage of a visual field without seeing the field itself. This phenomenon is shown to be closely related to ordinary afterimages and to temporal visual masking.

In order to observe negative afterimages reliably, it has usually been necessary that intense and/or prolonged stimulation of the eye by the stimulus object be followed by stimulation by a homogeneous grey or white field. This sequence of stimuli to the eye is usually arranged by voluntary eye movements. The negative afterimage appears against the white field in colors complementary to the stimulus and with brightness relations reversed. One exception to this procedure was described by Bidwell (*1*). Bidwell rotated a sectored disk in front of a red light. A typical presentation to the eye (repeated 6.25 times per second) consisted of (i) 80 msec of darkness, (ii) 20 msec of red light, and (iii) 60 msec of white field. Subjects reported the apparent color of the red light as cyan, the complement of red. Bidwell noted the similarity between the sequence of successive stimuli to the eye in observing afterimages by means of eye movements and the sequence in his procedure, namely, that a homogeneous, illuminated field immediately follows the stimulus. The difference is that, in the usual observation of negative afterimages, the sequence of images on the retina is controlled by relatively slow eye movements, whereas Bidwell used a mechanical control.

In the experiments reported here, a more flexible apparatus than Bidwell's rotating disk was used: a tachistoscope which permits the independent illumination of two optically superimposed fields. For example, if after a few seconds of dark adaptation, an observer is shown a card containing black letters on a white background (20 msec, 70 ft-lam) and this stimulus is followed immediately by a homogeneous white field (75 msec, 22 ft-lam) then he will report seeing bright *white* letters, clear and distinct, on a less white background. Similarly, a hand holding a (green) dollar bill appears as a pale green hand holding a pink bill, which demonstrates that the seen colors may conflict strongly with expectancy. Black and white as well as color photographic negatives look more like positives, and vice versa. If the presentation is recycled several times a second, a "continuous," color-reversed, flickering image is seen. Only by blinking in phase with the presentation, by strong squinting, or by sudden eye movements, all of which pervert the experimentally arranged sequence, is it possible to see the stimulus even briefly in its "natural" colors.

A simple prototype of the procedure described above for producing a continuing negative image was selected for quantitative study. A cycle time of 0.5 second was used because further increases in cycle time made little difference in results. From time 0.0 to time 75.0 msec of the cycle, a homogeneous 4×7 inch white field (masking field) was illuminated to a brightness of 46.5 ft-lam. The viewing distance was 40 inches. A 1-inch circle (test field), which was spatially superimposed on the masking field, was illuminated for less than 0.1 msec during each cycle. The energy of this test flash and its time of occurrence relative to the onset of the masking field (phase) were varied systematically.

Figure 1 shows the responses made by one observer to each stimulus presentation. Each point of Fig. 1 represents a particular stimulus presentation; all possible phases (-250 to $+250$ msec) are represented. The masking flash begins at time 0.0 and continues until time 75.0 msec. Thus, presentations in which the test flash precedes the masking flash are represented to the left of 0.0; presentations in which the test flash occurs during or after the masking flash are presented to the right of 0.0 msec.

The observer's responses fall naturally into two categories: those which indicate that he could see the test circle and those which indicate that the circle was not visible ("total masking" region of Fig. 1). The region of visibility may itself be further subdivided according to the appearance of the test field. Since the average energy density within the test circle is always greater than that of its surround, the test circle is usually seen as a light circle upon a darker surround. For some presentations, however, the observer reported that the test circle appeared to be darker than its surround. The limited range of phases and intensities for which this response was recorded are represented as the "reversal" region centered above 0.0 on Fig. 1. This "reversal" region indicates those stimulus presentations for which a negative image of the test field is seen without a prior positive image. For a closely related class of presentations ("ambiguous" regions, Fig. 1) the test field is seen as a circle of ambiguous

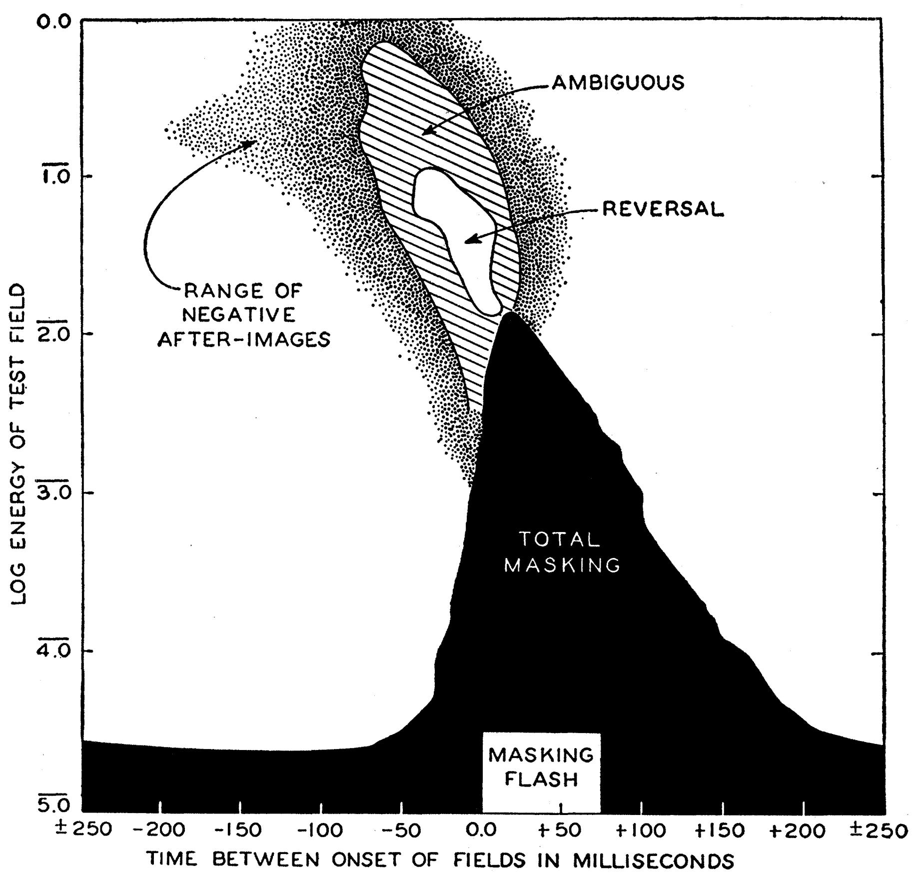

Fig. 1. Interactions between a small circular test patch and the masking field upon which it is geometrically superimposed. The test patch is flashed for 0.1 msec, and the masking field is flashed for 75.0 msec, beginning at time 0.0. As the energy in the test patch and its temporal occurrence relative to the masking field are varied, the reported appearance of the test patch may be a positive image, a negative image, an ambiguous image, or it may be masked completely.

brightness. In rapid succession it usually appears both darker and lighter than its surround. In all regions except the "masking," "reversal," and "ambiguous" regions the circle is seen as "positive," that is, as lighter than its surround. The subject was required to report on the presence of (subjective) afterimages as well as on the appearance of the test field itself. The stippled area of Fig. 1 represents the phases and energies of the test field for which reports of negative afterimages (of a prior positive image) were obtained.

The data of Fig. 1 confirm the qualitative statement that negative afterimages of a stimulus are seen when it precedes a homogeneous field. However, Fig. 1 shows much more. It demonstrates that good quantification is possible even of such an evanescent phenomenon as a negative image. The general topological properties of Fig. 1 remain unchanged for the many other kinds of visual stimuli that we have tried, including stimuli of different sizes, shapes, colors, and so forth. If the data are represented as in Fig. 1, then the area of "reversal" is contained within the area of "ambiguity" which, in turn, is contained within the area of "negative afterimages." Thus, areas of relatively more prominent negative images are contained within areas of less prominent negative images. This *invariant relation of containment* between the degrees of negative images constitutes strong evidence for their common origin. The particular negative images seen by Bidwell are a special case ("reversal" area) of the more general negative image phenomenon. The reversal conditions are simultaneously favorable for the negative afterimage and unfavorable for the positive image; therefore, only a negative afterimage and no prior positive image is seen.

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Reference

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A Simple Inexpensive Potometer

Abstract. A simple, inexpensive potometer, suitable for student use, is described. It differs from the conventional type mainly in that it does not contain a funnel and stopcock arrangement.

The conventional potometer, described in most textbooks of plant physiology (*1*), has become a widely used tool for the demonstration and measurement of transpiration. Although the apparatus really records the rate of water uptake, the rates of water uptake and water loss (due to transpiration) are, for practical purposes, often the same. Despite the limited usefulness of the potometer for research purposes, it is widely used in laboratory courses of plant physiology, mainly because it provides a rapid and very graphic means of illustrating and measuring the rate of water uptake under different environmental conditions.

In my experience with large classes of undergraduate students, it has rarely been possible to make wide use of the conventional potometer because of the cost of these potometers, the high rate of breakage, and the difficulty that students encounter in trying to lubricate the stopcocks. Clogged, leaking, or "stuck" stopcocks are all too commonly the cause of faulty results and broken potometers.

By modifying the conventional potometer, mainly by eliminating the funnel and stopcock arrangement, a potometer has been developed which is inexpensive and robust and which has proved to be accurate and very suitable for student use.

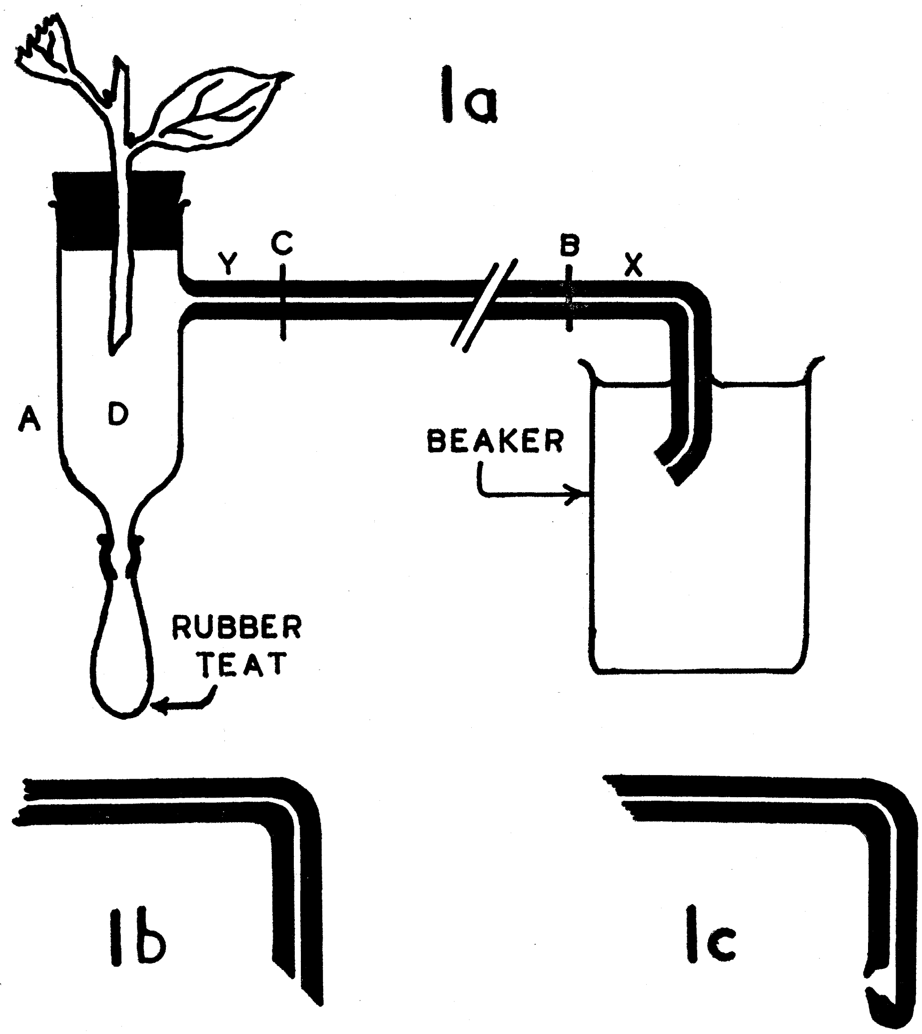

Fig. 1. The modified potometer.

The potometer (Fig. 1*a*) is set up in the usual way and is clamped to a retort stand at position *A*. Special care must be taken to make sure that the rubber teat is free of air bubbles. By lowering the beaker temporarily, an air bubble is drawn into the capillary tube. For a particular run, the air bubble is given time to travel a certain fixed distance (*B* to *C*) along the horizontal part of the capillary tube.

To prepare the apparatus for a second run, the air bubble is completely expelled from the capillary tube before it reaches the container *D*, by gently squeezing the rubber teat. The apparatus is refilled with water by gently releasing the pressure on the rubber teat.

As will be noted, the procedure with this apparatus differs from that with the conventional potometer in that (i) the apparatus is refilled with water from the beaker instead of with water from a funnel and stopcock arrangement attached to the capillary tube at *Y* in the conventional apparatus; and (ii) a fresh bubble must be collected before each run, whereas with the conventional apparatus, the same bubble is used in