of air is necessary to see if further flushing increases the counting rate.

The counter is operated with the amplifier gain set at X1–30, so that only pulses larger than about 2 mv are registered on the scaler. Under these conditions the relative counting rate for a $BaCO_3$ sample as a function of voltage is indicated in Table 1. Although the plateau

TABLE 1

COUNTING DATA

Voltage	Relative rate, R	Background, B*	$\frac{B}{R^2}$
1,500	0.64	0.9 cpm	2.2
1,600	1.00	2.3 cpm	2.3
1,700	1.06	4.8 cpm	3.9

* Partial lead shielding.

slope is rather more than that for a good Geiger-Müller counter, the voltage regulation has been found to be quite good enough to give consistent readings of activity relative to a standard.

It will be noticed from Table 1 that the background is low but that it increases more rapidly with voltage than the $BaCO_3$ counting rate. This may be accounted for by the variability and average smallness of cosmic ray ionization. In any case, this change of background with voltage poses a question as to what operating voltage is best for weak-sample counting. It can be shown that the background (B) divided by the counting rate (R) squared is proportional to the time required to count a weak sample to a given accuracy. Of the voltages shown in Table 1, 1,600 v was chosen for operation of the counter, since this voltage is in the plateau range and gives a low value of B/R^2.

The same criterion may be applied to compare this flow counter with a standard type of end-window counter used in this laboratory. Taking values of 0.4 and 0.16 counts per disintegration for the over-all efficiencies and 3 cpm and 24 cpm for the backgrounds, the flow counter is seen to be 50 times as fast for weak samples. This is equivalent to saying that, for a given time and percent accuracy, the flow counter can count samples which are weaker by a factor of $\sqrt{50} = 7.1$.

A test for coincidence losses was made by following the decay of a sample of C^{11}. The counting rate decayed from the initial rate of 86,000 cpm with a half-life of 21 min. The semilog plot of the data was straight within the counting errors, whereas if significant counting losses had occurred the data would have been below the line at the higher end. From the theory of proportional counter action one would expect the limitation on the maximum speed of counting to be imposed by the circuits of the register rather than by the counter itself.

Several measurements of self-absorption curves in the end-window and flow counters were made on the same sets of planchets. The samples were of different weights but of constant specific activity so that the counting rates would be expected to obey the equation, $N = N_\infty (1 - e^{-\alpha m})$. For both counters the experimental points above 3 mg/cm^2 were well fitted by this equation. The best values of α were found to be .31 cm^2/mg for the flow counter and .30 cm^2/mg for the end-window counter (*2, 4*). The ratio of counting rates was found to have a nearly constant value of about 2.6 except for samples of 3 mg/cm^2 or less. Between 3 mg/cm^2 and .5 mg/cm^2 the ratio increases from 2.6 to 3.1. This increase in the ratio for thin samples may be accounted for by soft back-scattered radiation which will penetrate neither the mica window nor the thicker layers of $BaCO_3$.

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Preliminary Report on a Device for the Objective Measurement of the Negative Afterimage Phenomenon

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The study of afterimages has received considerable attention by psychologists as well as physiologists for more than a century. Clinical application (*2–4*) of changes in the afterimage under pathological conditions has been attempted by several workers. A considerable difficulty in investigation of this phenomenon lies in the fact that until now the subject had to be trained for the observation of afterimages. Persistence, concentration, and a good measure of intelligence and reliability are required when reporting on the appearance, disappearance, and nature of afterimages produced after a subject has gazed fixedly for periods ranging from 5 to 30 sec at a brightly illuminated object.

An experiment first described by Bidwell (*1*) has been the basis for the development of an instrument which makes it possible to obtain reliable measurements of some aspects of the negative afterimage, under conditions that make it unnecessary to train the subject for his observations. Since only the afterimage and not the original stimulus is perceived with this method, there is no shift of gaze or attention, an end point can be determined on a measuring scale, and observation becomes so simple that even children and mentally disturbed patients may be studied without sacrificing too much of the reliability of the results.

If a disk, half white and half black, with a sector cut out as a window, is rotated at a certain speed in front of a brightly illuminated colored object in such a manner that first the object through the window, then the white part, and, finally, the black part of the disk are exposed

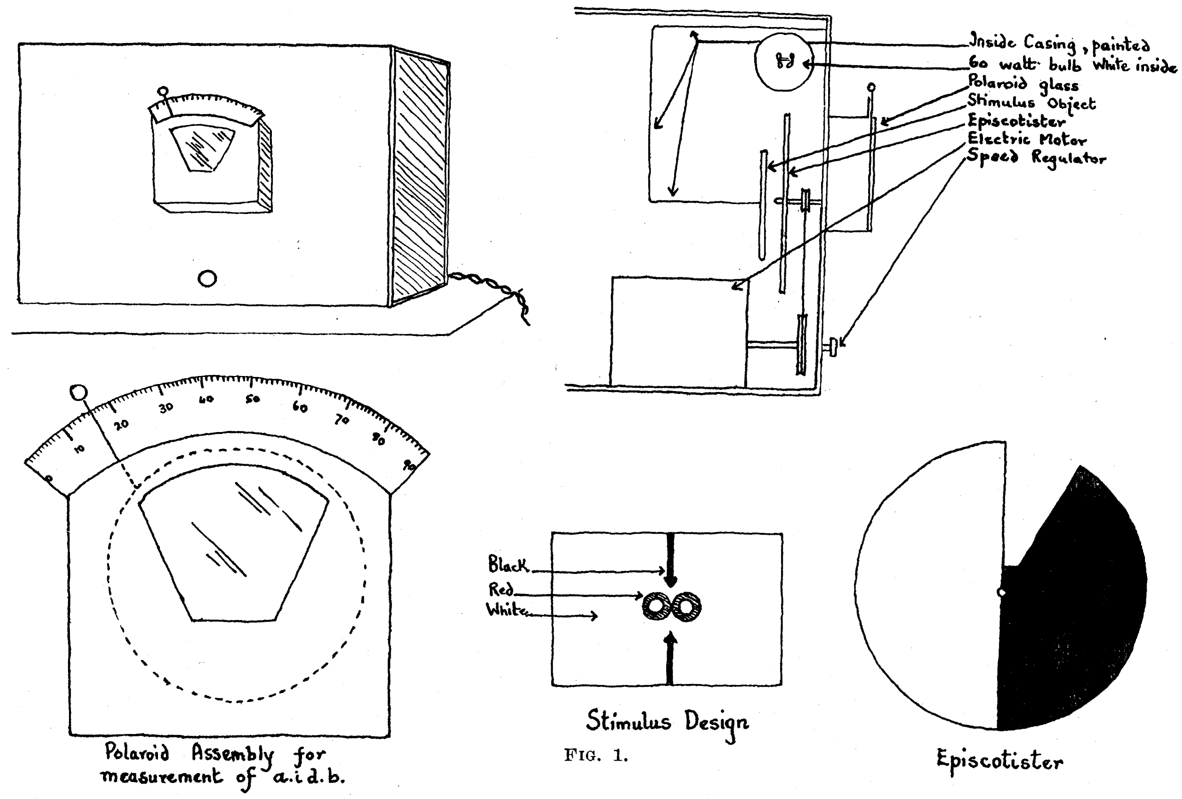

FIG. 1.

to the eye, a negative afterimage in complementary colors is projected onto the rotating disk. The significant difference in the refractory time of the unit of the retino-cortical system responsible for the perception of the afterimage and the unit responsible for the reception and signal conduction of the original stimulus makes it possible to arrange conditions so that the original stimulus never reaches consciousness, although it is constantly operating to maintain the afterimage in the field of conscious perception. Thus, a red circle will appear green to the observer who is unable to see the original color at any time. The principal variables of this effect are the speed of rotation of the disk, and the brightness of illumination of stimulus object and disk. Brightness of illumination proved to be the more practical variable with regard to quantitative measurement. A certain minimum brightness is required for the production of an afterimage. This minimum brightness has a fairly constant value for the same individual under similar conditions. It can be measured easily, as the complementary color of the afterimage changes into the original color of the stimulus when this threshold value has been reached, by gradually dimming the light that reaches the eye from stimulus and disk. This value will be referred to as afterimage disappearance brightness (a.i.d.b.).

Various methods of regulating the brightness of stimulus and disk were tried. An optical method had to be employed, since regulation of the electrical power supply to the incandescent source of illumination influences the color of the light, and thus introduces another variable. Control of brightness was finally achieved with two polaroid glass filters interposed between the rotating disk and the observer's eye. These filters make it possible to regulate the amount of light reaching the eye from the original stimulus, and to determine the threshold value necessary for the production of a negative afterimage. Since the appearance and duration of afterimages are functions of the factor of illumination, one measures the "susceptibility" to negative afterimages by dimming the light until either no afterimage is produced, or its duration is so brief that it does not persist long enough to prevent the perception of the original stimulus. The polaroid filters allow for a rotation of 90°, and the angle at which the last trace of the complementary color of the afterimage has disappeared and the stimulus object is perceived entirely in its original color, is determined on a scale. The dimming of the light may be done by the observer himself or by another person. Most other workers have dealt with the quantitative aspects of afterimage lag and afterimage duration. Our method is concerned with the measurement of the threshold value of the illumination necessary for the production of afterimages.

Since brightness of illumination serves as the measured variable, it is essential to keep all other factors constant. Speed of rotation of the episcotister is kept constant by adjusting it with friction brakes or a rheostat, until a stroboscopic disk mounted on the back of the episcotister shows that it turns at 5 rps.

Fig. 1 gives a schematic illustration of the apparatus. The insets show the episcotister, the polaroid eyepiece, and the stimulus design we have been using. The source of illumination is a 60-w incandescent bulb, 5 in. above the center of the stimulus card and 5 in. above the center of the front of the episcotister. It is arranged so that it illuminates the stimulus object as well as the front of the episcotister. In another model it might be better to have independent sources of illumination for the stimulus object and the episcotister. It seems that a more intense complementary color is produced if the stimulus object receives more light than the episcotister, although the latter has to be strongly illuminated also. Lamp, stimulus object, and the upper part of the episcotister are encased in a metal box painted white, while the inside of the rest of the apparatus is painted black.

The episcotister is made of plywood or metal (diam 8.5 in.). Half of it is painted white; the other half of the episcotister is covered with black velvet (and of this part a sector of 30° is cut out to serve as a window, behind which the stimulus object is presented).

The stimulus object consists of a card 5 in. × 6 in. with the design as shown in the illustration. The arrows are black, the two circles bright red, the background white. Letters, numbers, or pictures may be used instead of the "abstract" design, but associations to meaningful stimuli would probably introduce into the set another psychological variable, mainly determined by neurophysiological factors. Red as a stimulus color produces the best afterimage under the conditions of this experiment.

The polaroid assembly consists of two round polaroid glass filters of fairly neutral gray tint. They are mounted under a scale on which the angle of rotation of the filter is read.

The subject is instructed to look with both eyes through the filters at the stimulus object. The filters are set at zero, i.e., maximum brightness. The subject hears the noise of the motor but is often unaware of the fact that an episcotister is rotating between the eyepiece and the design he sees. He is asked to describe what he sees and to name the color of the design. The filter is then rotated about 80°, thereby changing the color of the circles from light green to red. The filter is returned to the zero setting, and the subject is asked to indicate at which point the color change from green to red is completed. On our instrument the lowest reading of one subject was 40° while others gave readings between 75° and 80°. The majority of readings lay between 50° and 70°.

Observations to be published in detail have shown the a.i.d.b. to be influenced by fatigue, cerebral anoxia, and pharmacological agents. A.i.d.b. also changes with the age of the individual. Children before puberty and some patients with mental disorders may show qualitative deviations and may be unable to see the complementary color. Patients with convulsive disorders seem to possess certain characteristics with regard to their susceptibility to negative afterimages. A certain relation between critical flicker fusion frequency (c.f.f.f.) and afterimage disappearance brightness seems to exist, but there is little doubt that the c.f.f.f. and a.i.d.b. measure two different functions of the perceptual apparatus.

The theory of afterimages is still under discussion. The instrument described here could certainly be improved. It provides, however, for the first time, a means to study objectively some aspects of a complex problem.

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A Preliminary Investigation of the Relationship between Visual Fusion of Intermittent Light and Intelligence

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The evidence that critical flicker frequency is a centrally limited phenomenon is so strong, it seems possible that it may furnish a method for the study of some aspects of the central nervous system in its natural habitat. Halstead (*3*) presented evidence that the point of fusion is related to other central phenomena, but is not related to visual acuity. Misiak (*4, 5*) reported that the point of fusion for individuals is not related to visual acuity, varies with age above 30 years in a manner very similar to the raw scores of the Wechsler-Bellevue Intelligence Test, and does not improve with practice. Halstead, however, found only low correlations between his flicker-fusion frequency scores and scores on two intelligence tests. These correlations, nevertheless, were positive.

Halstead's apparatus employed a 10-μsec light flash. For frequencies of the magnitude reported by Halstead —approximately 20 cycles/sec—a 10-μsec flash means that the light-dark ratio was 1: 5,000. Bartley (*2*) reported that the subjective brightness of intermittent light varies with frequency at frequencies below fusion in such a manner that brightness could very easily have functioned as a confusing variable. For light-dark ratios of 1: 1 or greater, the subjective brightness becomes greater as frequency increases until the alpha frequency of brain waves is reached, and then decreases until it reaches the Talbot level at the point of critical flicker frequency. Subjective brightness reaches at its maximum a level that is about as far above that of a steady stimulus of an equivalent intensity as the Talbot level is below. Only an experimental study could determine the extent to which subjective brightness may have been a confusing factor in Halstead's study.

A second factor in Halstead's study that may have affected his findings was the fact that the frequency of the stimulus was varied by the observer. To what extent, if any, such a procedure influences the determination of a subjective phenomenon such as flicker-fusion is not known, but it may have been significant.