

THE EFFECT OF DARK ADAPTATION AND OF LIGHT UPON
THE ELECTRIC THRESHOLD OF THE HUMAN EYE

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When an electric current of adequate strength is passed through the eye, a visual sensation or phosphene is perceived. With strong currents the sensation may be colored, but when strengths close to threshold are used a whitish flash is perceived which is strongest in the peripheral part of the visual field, and closely resembles the flashes produced by alternating magnetic fields. In our previous paper (Barlow, Kohn and Walsh, 1946) some evidence was given localising the structures sensitive to magnetic fields and alternating currents to the retina. In order to define more closely the structures sensitive to electric currents we have investigated the effect of dark adaptation and of light upon the threshold for electric stimulation.

This problem has been investigated previously by a number of workers but the results are somewhat contradictory; for instance, of the authors who stimulated with D.C. three (Muller, 1897; Nagel, 1904; Bruckner and Kirsch, 1913) found no change in threshold during dark adaptation, whilst the later workers (Bogolovsky, 1934; Bouman, 1935; Schick, 1935) found an increase. More consistent results were obtained by the workers who stimulated with condenser discharges; all five agreed that the rheobase increases during dark adaptation (Verrijp, 1925; Achelis and Merkulow, 1929; Fischer and vom Hofe, 1932; Gersuni, 1935; Katasima, 1939). A discontinuity in the strength duration curve for the light adapted eye was found by Achelis and Merkulow (1929) but not confirmed by later investigators, and Bouman suggested that this kink was the result of random variations. A study of these papers shows that the chronaxie does not change, or changes very little with dark adaptation; on the other hand there is apparently a ten fold increase in the rate of accommodation during dark adaptation (Bouman, 1939). One author (Lasareff, 1924) stimulated with faradic current and detected no changes, and Cords, (1907) using A.C., also reported no change in the maximum frequency at which flicker could still be perceived.

Three papers have dealt with the effect of increased illumination on the threshold. Fischer and vom Hofe (1932) and Schick (1935) found an increase in rheobase, whilst Bogolovsky (1934), who covered the eyes during the determinations of threshold, found a transient decrease.

A study of these papers coupled with our own results leads us to believe that most of the discrepancies are more apparent than real, being due to differences in technique. During the course of this work it has become apparent that light plays a dual rôle. Depending on the attendant circumstances, both with respect

to previous as well as immediate exposure, light may either lower or raise the electric threshold.

METHODS. A conventional circuit was employed to deliver condenser discharges at a rate of 20 to 30 per minute. Switching was accomplished by an automatic cam operated contact breaker and stimulation was maintained for the shortest time necessary for the determinations. A 100,000 ohm resistance was connected in parallel with the electrodes to minimise polarisation, and a series resistance, of the same value, was connected in the circuit to minimise the effects of changes in skin resistance. The electrodes were cloth covered copper discs, 3 cm. in diameter, moistened with saturated sodium chloride solution and held firmly in place on the forehead and forearm.

The subject sat erect fixating a small mark on a cream colored wall whose reflection factor at 90° was 0.75. The illumination was varied by using electric lamps of different strengths and was measured with a comparison photometer calibrated against a Macbeth Illuminometer. Dark adaptation was achieved either by extinguishing all lights or by placing a small opaque mask over the subject's eyes. The course of dark adaptation was followed by light stimuli from an adaptometer (Wald, 1941). Threshold was taken as the peak current eliciting a flash in half the trials.

To obtain consistent values it was necessary to control certain details of the procedure:

1. The interval between successive shocks should be at least two seconds, because at shorter intervals fatigue is encountered.
2. The position of the eyeball relative to the rest of the orbit affects the threshold. It is therefore necessary to control the position of both the eye and the head during the determinations.
3. The eyelids should be open during the determination, in the light, or in the dark, since closing them may raise the threshold 100 per cent.
4. The subject should be comfortable; experiments should be relatively short in order not to tire him.

RESULTS. The effect of light and of dark adaptation upon the electric threshold of the eye is illustrated by figure 1. In this instance, typical of 18 such experiments, the subject was exposed to light at zero time, and his threshold determined 14, 25 and 36 minutes thereafter ranged between 0.3 and 0.34 milliampere (50 msec. discharges). At 44 minutes all light was extinguished, and 1 minute later the threshold had dropped to 0.12 milliampere. Five minutes later it had risen to 0.25, and subsequently it rose smoothly, reaching a plateau value of 0.44 milliampere after approximately 40 minutes of darkness. The electric thresholds in this experiment were not all equally easy to obtain. In the light and during the first part of dark adaptation the threshold seemed fairly sharp. After 10 to 15 minutes in the dark, however, the "threshold region" broadened, that is to say, the subject found it increasingly difficult to decide just when the phosphene was no longer elicited.

For comparison, the visual dark adaptation curve, determined in the same experiment, is also shown in figure 1, the scale of thresholds being plotted in log

millimicrolamberts. While the electric threshold rose the light threshold dropped from more than 4 to less than 2 log units in the course of about 40 minutes.

These results are not substantially affected by changes in skin resistance since similar ones were obtained using subcutaneous needle electrodes. Changes in pupillary diameter are likewise unimportant as was shown by the use of physostigmine and homatropine.

Changes in the time constant of condenser discharge, tested from 3 to 50 milliseconds, changes the absolute but not the relative values. An example of this is shown in figure 2, where the curves for 10 and 50 milliseconds are compared.

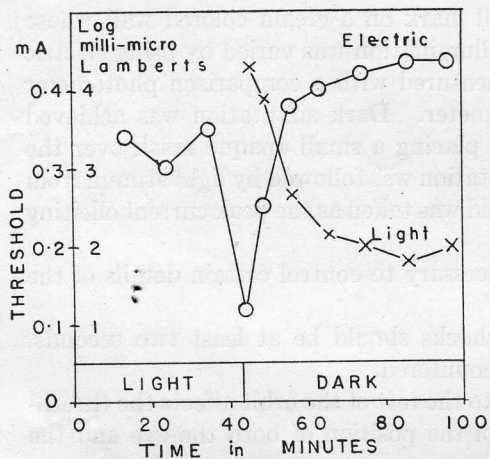


Fig. 1

Fig. 1. Changes in the electric and light thresholds of the eye during dark adaptation. The electric thresholds (50 millisecond condenser discharges) in milliamperes are plotted as the open circles. The light thresholds in log millimicrolamberts are plotted as crosses. Following the exclusion of light at the 43rd minute, there was an immediate fall in electric threshold, which then gradually rose during the next 40 minutes while the light threshold was falling.

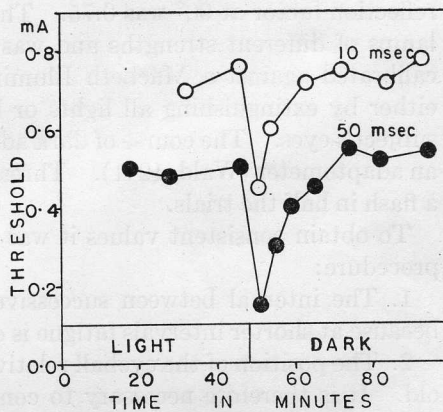


Fig. 2

Fig. 2. Electric thresholds for 10 and 50 millisecond condenser discharges during dark adaptation.

The longer stimulus merely results in a lower absolute threshold throughout the course of the curve. The threshold determined as a function of duration of condenser discharge showed that the chronaxie was approximately 1.8 msec. both at full dark adaptation and at adaptation to one foot-candle. In other experiments direct current pulses lasting about 0.8 second were used as stimuli and similar results were obtained. In this instance, however, a flash was seen both when the circuit was made and also when it was broken. For the dark adapted eye the make and break thresholds were equal, or nearly so, but for the light adapted eye the break threshold was considerably higher than the make. When the dark adapted eye is exposed to light there is an immediate large in-

