# THE STUDY OF ORIENTING REACTIONS OF THE PUPIL TO LIGHT*

A. Ya. Samoilov

(Presented by Active Member AMN SSSR V. V. Parin)

Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 50, No. 8, pp. 33-37, August, 1960
Original article submitted July 5, 1959

The theory of orienting reflexes has undergone much development in recent years and, thanks to the investigations of E. N. Sokolov [7], has attracted considerable attention among physiologists and clinicians. A highly convenient object for studying orienting reflexes is the pupil of the eye, which is very responsive to any external stimulus.

Special investigations of the duration of the latent period, rate, and amplitude of contraction and dilatation of the pupil, etc., have been undertaken repeatedly for the purpose of utilizing these reactions in delicate functional diagnosis [1, 2, 8, 12]. Substantial difficulties have arisen, however, in connection with methods of recording the movements of the pupil. In this respect, the objective and precise method of cinematic recording of pupillary contractions proposed by A. R. Shakhnovich in 1956 is very useful [9]. Subsequent development of the techniques has led to the creation of the new method of local pupillography [3, 4].

The study of pupillary reflexes with the aid of the method of local pupillography has shown that pupillary contractions observed immediately after illumination of the normal eye have a twofold character. The clear-cut miosis that occurs in response to a strong light stimulus is a species of typical defense reflex. At the same time, the very similar pupillary contractions that follow less intense illumination have features that are more characteristic for reflexes of the orienting type [10]. In themselves these contractions of the pupil are very similar – they have the same latent period (0.2 sec), they take place at approximately the same rate (between 0.5 and 0.7 sec from the beginning of contraction to the attainment of maximum miosis), and display very little difference in amplitude of contraction. These characteristics of the course of reactions of the normal pupil to illumination, which have been studied in detail by Löwenstein [15], are seen distinctly in many of our pupillograms. But the gradual extinction of pupillary reactions to repeated illumination, which Löwenstein calls the phenomenon of "pupillary fatigue," has not been confirmed in the experiments of other investigators [13].

Employing bright lights, we also were unable to demonstrate, with a precise graphical method, any signs of a reduction in the amplitude of pupillary contractions in response to light, even after 100, 200, or more repeated illuminations [5]. At the same time, weaker illuminations (of approximately 0.2 stilbs or less) invariably were accompanied by extinction of the reflex, which set in the more rapidly, the less the intensity of the applied stimulus – the light.

This difference in the reactions to strong and weaker illumination in the presence of a definite end point – the threshold of development of pupillary reflexes that are extinguished and those that are not – permitted us to conclude that we are dealing here with two essentially different types of pupillary reflexes: a defense reflex to strong light, which is not extinguished, and a reflex of the orienting type to less intense illumination, which is extinguished.

The great outward similarity of pupillary contractions of these two types caused us to attempt to construct experiments in which the difference in the character of the pupillary reflex could be demonstrated not only by employing repeated light stimuli, but also directly, at the very first examination. For this purpose we decided to undertake prolonged illuminations of the eye with light of various intensities.

## METHOD

Whereas, in giving a brief stimulus, we switch the light on for exactly 0.2 second – in the expectation that the whole period of stimulation will fall within the latent period of the pupillary reflex, and that by the time the pupil begins to contract, the light will no longer be acting on the eye – for a prolonged stimulus we decided to use a 3-second illumination of the eye. With brief stimulations (lasting 0.2 second), the time elapsing between the moment of switching on the light, and the moment when the whole reaction is over and the original pupillary diameter is restored to normal, is 1.2-1.5 seconds, including the entire latent period, the period of contraction, and the period of dilatation. On the basis of this interval, a duration of prolonged illumination was chosen in our experiments equal to twice

*All experiments were performed in the eye-examining room of the Institute of Neurosurgery, AMN SSSR.

the period of maximum duration of the physiological pupillary reflex to a brief illumination – i.e., three seconds.

In both brief and prolonged illumination, we produced focal illumination of only a small area in the region of the most posterior portion of the retina – in the zone of the macula lutea. As in all previous experiments, we used faint background illumination for taking photographs, with an intensity of about 25 luxes at the level of the eye being examined. For all our photographs the bulbs, shielded with frosted glass, used for background illumination were placed beneath the eye being photographed, considerably below the line of sight. This location is very convenient for taking photographs, since the light from the background lamps falls on the iris at such an oblique angle that almost none passes through the pupil to the retina, whereas the principal immediate object of cinematography – the iris – is illuminated with sufficient intensity. Figure 1 shows a diagram of the arrangement of the object of fixation (from which the eye is illuminated ), the mirror used to direct the strongly stopped-down, narrow beam of light through the pupil onto the retina of the eye being examined, and the lamp for background illumination, in relation to the eye of the observer. This arrangement of the background lamps explains the fact that in our experiments the pupil initially has a diameter of 6-7 mm, i.e., it is not much narrower than in complete darkness. If, at the same intensity of background illumination, the subject fixates on the illuminating lamps, the diameter of the pupil immediately decreases to 4.5-5 mm. In a table presented in Schober's book [16], which was taken from Hartinger's work [14], it is found that the mean pupillary diameter at an intensity of illumination of 10 luxes, at the level of the eye being examined, averages 4.97 mm; and at an intensity of 100 luxes, it is only 3.92 mm for the normal human eye.

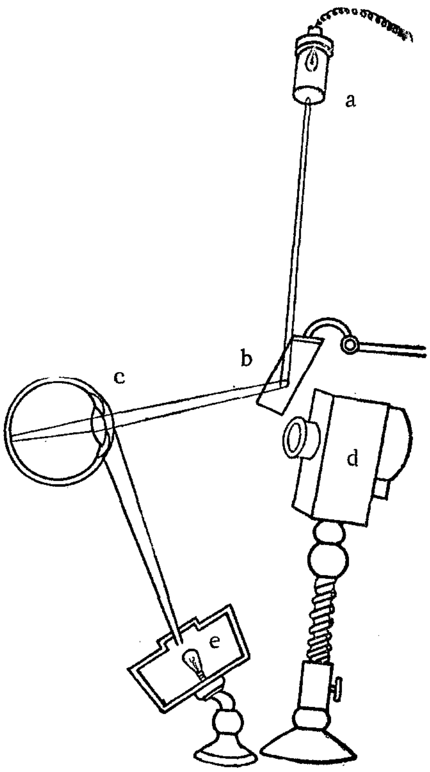


Fig. 1. Sketch of arrangement of illuminating system in local pupillography. a) Fixation object and lamp for illumination; b) mirror used for fixation and illumination of eye; c) eye being examined; d) motion-picture camera; e) lamps for background illumination.

In all our experiments we have taken motion pictures at a speed of 10 frames a second, which permits us to trace all the individual moments in the course of the pupillary reflex, and at the same time, does not yield curves that are too flat and stretched-out. Each vertical line on our pupillograms represents 0.1 second.

## RESULTS

The reactions of the normal human pupil to bright illumination of various durations are shown in the pupillograms depicted in Fig. 2. On the left the figure shows a pupillogram obtained with brief illumination lasting 0.2 second. The pupillogram on the right represents the pupillary reaction to illumination of the same intensity, but lasting three seconds. The initial pupillary diameter of the eye being examined was approximately 6 mm in both cases.

It can be seen from Fig. 2 that after latent periods of the same length in both cases (0.2 second), contraction of the pupil began and took place at roughly the same rate; and that this pupil, with both brief and prolonged illumination, contracted to 4.75 mm in diameter by the 5th frame after the beginning of contraction (the 7th frame from the beginning of illumination), after which it began to dilate again in the case of brief illumination, until, by the 12th frame from the start of illumination, it again returned to its initial diameter.

With prolonged illumination the initial course of pupillary contraction is exactly the same, but contraction of the pupil does not end at the seventh frame – it continues further at the same rate. The pupil does not reach minimum dimensions until the 9th frame after the beginning of illumination, i.e., until a time when, with brief illumination at the same intensity, a considerable degree of pupillary dilatation has already occurred. Corresponding to the longer period of pupillary contraction, its constriction is here more pronounced. In the ninth frame after the beginning of illumination, the pupil has a total diameter of 4.5 mm and remains this narrow as long as the light is applied. After the light is turned off, the pupil remains maximally constricted for another 0.3 second, and then begins to dilate gradually. The process of pupillary dilatation to a diameter of roughly 5.5 mm occurs at the same rate as with brief illumination, and lasts for 0.5 sec, after which the rate of dilatation slows markedly, so that even by the end of the recording (2 sec after the light is turned off), the pupil still does not entirely reach its initial diameter.

The course of pupillary reaction to weak illumination of different durations is shown in Fig. 3. In this figure, as in the preceding one, the left pupillogram corresponds to a brief illumination lasting 0.2 second. The differences between this and the pupillary reaction to brief stimulation of the eye with light of ten times greater intensity take the form only of somewhat less intense miosis in response to the weaker illumination, but neither the duration of the latent period nor the over-all configuration of the pupillograms shown in Figs. 2 and 3 suggests that the pupillary reflexes to brief illumination of the eye with bright and dim light are different in principle. But clear-cut essential differences in the pupillary reflexes to illumination at high intensity (approximately 2 stilbs) and at low intensity (approximately 0.2 stilb) are immediately apparent when we compare the two pupillograms obtained with prolonged illumination of the eye at the two different intensities.

On the right side in Fig. 3 is shown a pupillogram obtained with prolonged illumination of the eye with a weak light (roughly 0.2 stilb). It is noteworthy that the constriction of the pupil in response to prolonged illumination exactly reiterates the pattern of its reaction to brief illumination at the same intensity. With both prolonged and brief illumination, after a latent period of 0.2 second, a very slow pupillary constriction lasting 0.5 second began, with the pupil constricting from its initial 6 mm to only 5.2 mm. After this period of maximum constriction, with both brief and prolonged illumination a gradual dilatation of the pupil began, taking place somewhat less rapidly than had the constriction. In complete contrast to the reaction to prolonged illumination at high intensity, during prolonged stimulation with a dim light–despite continued application of the light–the pupil again dilated and, in the tenth frame from the beginning of dilatation, again reached its original dimensions. Switching off the light produced no new changes in the diameter of the pupil.

If we compare the pupillograms obtained with prolonged illumination of the eye with bright and dim light, we become convinced of the fact that we are dealing with two reflexes that are essentially different. Stimulation with strong light gives a stable miosis that lasts as long as the application of the stimulus continues, which corresponds to our conception of a pupillary reflex of purely defensive character, directed toward a reduction in the total number of light rays entering the eye and stimulating the light-sensitive elements of the retina. When the amount of light entering the eye is no longer excessive, the pupil again dilates to its previous dimensions.

The pupillary reaction to a dim light proceeds in an entirely different fashion. In this case the pupillary contraction to prolonged illumination takes exactly the same form as the contraction to a brief light of the same intensity, since the novelty of the stimulus is the basis of the reaction. Just as repetition of a series of brief, faint illuminations has the result that the pupil stops reacting to them with constriction, so also, with prolonged illumination at low intensity, the contraction of the pupil caused by the appearance of the light immediately disappears as soon as the influence of the light loses the element of novelty. Thus, the entire course of the pupillary reaction to prolonged illumination at low intensity compels us to regard it as an orienting reflex to something new. From these premises it becomes possible to understand how the reflexes to brief and to prolonged illumination at low intensity are completely alike, and coincide in all respects with pupillary reflexes to changes in the form or color of the fixated object, which have been described in the work of A. R. Shakhnovich [11].

Thus, the use of prolonged illumination allows us to determine immediately whether we are dealing with pupillary contractions of a defensive or an orienting character, and this in turn may have some practical importance for the clinic, e.g., in topical diagnosis of certain forms of brain disease. In a previous paper [6]

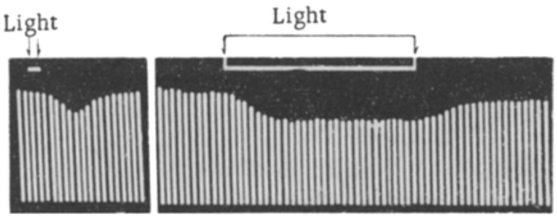


Fig. 2. Contraction of pupil under the influence of a bright light (about 2.0 stilbs). On the left – effect of brief illumination lasting 0.2 sec; on the right – effect of prolonged illumination at the same intensity (lasting 3.0 sec).

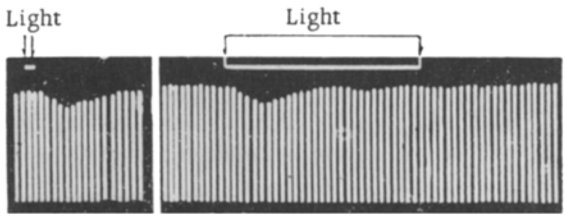


Fig. 3. Contraction of pupil under the influence of a dim light (about 0.2 stilb). On the left – effect of brief illumination (0.2 sec); on the right – effect of prolonged illumination (3.0 sec) at the same intensity.

we noted that, in lesions in the region of the visual funiculi, we observe a loss of pupillary contractions of both the defensive and the orienting character. On the other hand, in cortical lesions only the orienting pupillary reflexes are lost, and not the defense reflexes. The possibility of determining quickly and accurately whether a lesion is a purely basal one in the area of the visual or oculomotor tracts, or whether the patient is suffering from disturbances in the cerebral cortex, can hardly be overrated, especially if we are concerned with comparatively small, localized inflammatory foci that are not manifested in clear-cut neurological symptoms, or the earliest stages of development of brain tumors.


SUMMARY

Pupillary constriction to light may take the form of defense or orienting reflexes. To distinguish the reflexes of these two types, the author suggests prolonged, instead of brief, exposure, to light; in the first case the defense reaction gives a stable miosis lasting throughout the exposure period, whereas the orienting reaction takes the form of a brief constriction of the pupil, which then resumes its former size despite continued exposure to the light.

The possibility of promptly distinguishing defense from orienting reflexes is of practical, as well as theoretical, significance, since loss of the defense reaction of the pupil to light points to a basal localization of cerebral lesions, involving visual or oculomotor pathways; on the other hand, loss of the orienting reflex alone points to a cortical localization of the lesion.


LITERATURE CITED


1. G. V. Gershuni, Fiziol. Zhur. SSSR 5, 541 (1949).
2. V. D. Glezer, Fiziol. Zhur. SSSR 5, 604 (1952).
3. A. Ya. Samoilov and A. R. Shakhnovich, Vestnik AMN SSSR 4, 47 (1958).
4. A. Ya. Samoilov and A. R. Shakhnovich, Voprosy Neirokhir. 3, 20 (1958).
5. A. Ya. Samoilov and A. R. Shakhnovich, Vestnik AMN SSSR, 4, 36 (1959).
6. A. Ya. Samoilov and A. R. Shakhnovich, Vestnik AMN SSSR 4, 41-42 (1959).
7. E. N. Sokolov, Perception and the Conditioned Reflex [in Russian] (Moscow, 1958).
8. N. P. Tatarenko, Zhur. Nevropatol. i Psikhiatr. 2 153 (1954).
9. A. R. Shakhnovich, Fiziol. Zhur. SSSR 8, 632 (1956).
10. A. R. Shakhnovich, Author's abstract of Cand. Diss.: The Pupillary Component of the Orienting and Defense Reflexes [in Russian] (Leningrad, 1958).
11. A. R. Shakhnovich, Biofizika 4, 367 (1959).
12. A. R. Shakhnovich, Fiziol. Zhur. SSSR 2, 170 (1958).
13. C. Cüppers, Klin. Monatsbl. Augenheilk. 119, 411 (1951).
14. H. Hartinger, Ztschr. f. Ophthal. Opt. 14, 148 (1927).
15. O. Löwenstein, Arch. Ophth. 55, 565 (1956).
16. H. Schober, Das Sehen (Leipzig, 1957).