ON A PHOTOGRAPHIC METHOD OF RECORDING THE REACTION OF THE PUPIL IN ABSOLUTE DARKNESS AND IN BRIGHT LIGHT.

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By the method which I propose to describe, we are enabled to photograph the pupil at its two extremes of functional activity; that is to say (1) in the condition resulting from prolonged rest in darkness, and (2) in that resulting from exposure to strong light. These two classes of photographs are obtained, respectively, by (1) explosive magnesium mixture, (2) burning magnesium ribbon. It is especially with the first of these two methods, however, that I propose to deal - that by which we can photograph the eye in, so to speak, complete darkness, the essence of this method being dependent on the fact that a flash can be produced, so rapid and so brilliant, that a clear photograph of the eye is taken before even the commencement of the resulting reflex contraction of the pupil.

It is to two German scientists, HH. Miethe and Gädicke, that we are indebted for the invention of the now well-known explosive magnesium mixture, and the former worker, at the instigation of Dr Claude du Bois-Reymond of Berlin, further prepared, in 1887, the first published photographs taken by this method. An abstract of a paper on the subject, read by Du Bois-Reymond to the Physiologische Gesellschaft at Berlin is printed in the "Archiv für Physiologie" and in the "Centralblatt für praktische

Augenheilkunde", both of 1888; a few paragraphs by him in English, together with a reproduction of one of Miethe's eye-photographs, may also be found in "Nature" for May 3rd of the same year. About the same time somewhat similar experiments were being made by Prof. Hermann Cohn in Breslau, but the idea of iris-study by flash-light apparently originated with Du Bois-Reymond.

Previous to this discovery by Miethe and Gädicke, the effect of complete darkness on the pupil had only been seen by the light of electric discharges, etc., which allowed of no measurement or detailed examination.

The explosive substance used by these observers was a finely powdered mixture of magnesium and salt-petre, which, as I have said, affords so rapid and yet so bright a flash that a fully exposed photograph of the eye can be secured when the pupil is in a condition of maximum dilatation, the beginning of the pupillary contraction only taking place in the darkness following the flash. (Cl. du Bois-Reymond, loc. cit.)

This phenomenon had already struck the discoverers when they first began to take photographs of human faces and groups of persons by their flash-light method; the eyes showed a peculiar, somewhat staring expression, owing to the fact that the condition of the pupils did not appear to correspond to the surrounding illumination ["weil der Zustand der Pupillen nicht, wie wir ihn sonst zu sehen gewohnt sind, der Helligkeit des übrigen Bildes entspricht." (ibid.)].

My aim is to consider a method, which, as it is quite simply carried out, may perhaps prove itself a useful addition to the clinical methods at present in common use: it is especially adapted for those cases of disease of the nervous system in which the mobility of the pupil is impaired.

My object being, as I say, primarily to describe a method, rather than to deal, more than in passing, with any special conclusions arrived at by its application, it may be as well if I refer shortly to my early and less successful attempts as well as to the ones which led to more satisfactory results.

To begin with, I took one or two preliminary photographs by ordinary methods, using a tripod stand, etc. It became at once evident, however, that much time would be lost in adjusting the camera to each separate case, and in keeping the sitter's head steady during the long wait necessary before the flash (15 mins.). Some more rigid and easily adjustable contrivance was obviously necessary.

The plan which I finally adopted was as follows:- the apparatus is fixed to a firm deal table, at which the patient sits, his chin resting in a ∪-shaped notch at the top of a vertical board: a horizontal board in front of this head-rest bears at its extremity the stand of the camera. Lateral movement of 3 in. is obtained by means of a small sliding base, which permits the camera to be so moved that either eye can be readily brought into the centre of the photographic field. Antero-posterior movement is secured by a rack and pinion adjustment.

At the beginning of the experiments the camera was carefully focussed, so that the image thrown upon the ground-glass was of natural size; thereafter, in each individual case the eye was brought into exact focus by the rack and pinion of the stand, the relative positions of eye, lens, and plate being thus the same in every case.

In order to make certain that the photograph will be "life-size", it is best to include in it an object of known size, fixed alongside the eye in the same coronal plane as the iris, and of which we possess a duplicate; this latter is laid against

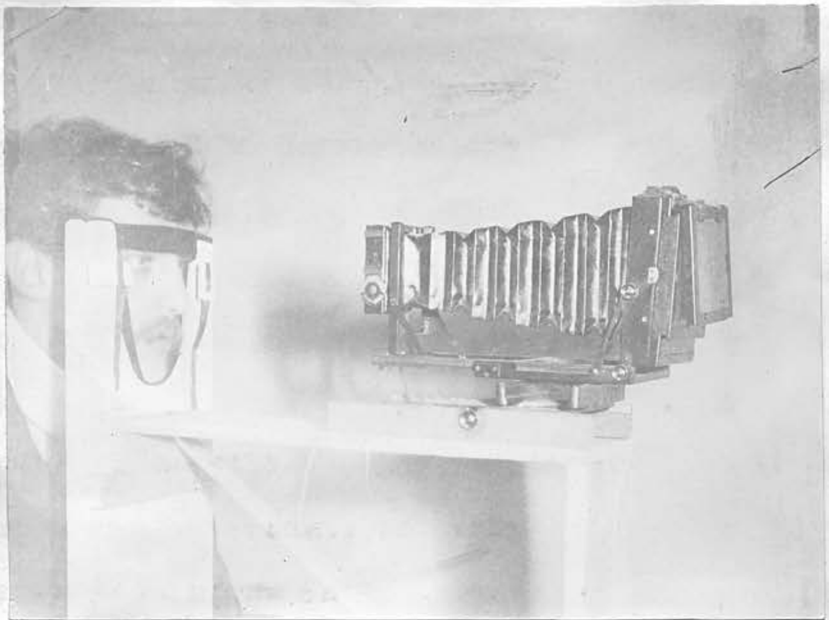

Fig. 1.

the focussing-screen, and the camera is then easily adjusted till the image and the duplicate on the screen absolutely coincide. For this purpose I have used a millimetre scale printed upon thin paper, which, besides subserving this main object and being readily replaced if lost, is also useful in the resulting photograph, as giving an estimate of the size of the cornea, iris, pupillary aperture, etc.

Within recent years other more complex methods of pupillometry have been devised, notably those of Morton, Haab, and Schnabl, the "strabometer" of Lawrence, the projection method of Schirmer, and especially that of Du Bois-Reymond himself by magnesium flash-light (a).

For our purpose, however, which is not primarily a pupillometric one, I have found the simple method above described amply sufficient: with each photograph I also give the transverse measurement of the pupil in figures. The whole apparatus, in working order, is seen in Fig. 1.

On account of the shortness of exposure (i.e., the duration of the flash), it is necessary that the lens be used at full aperture. I used a Taylor, Taylor, and Hobson lens, of 4½ inch focus, working at £ 7, having found that this gave excellent definition.

Though theoretically there is only one plane in focus, I found that, in practice, an antero-posterior movement of the camera through 6 mm. could be allowed, without impairing the sharpness of the image.

The plates used were "Imperial Flash-Light" (quarter plate.)

Of the various sources of artificial light available for photography, we need only consider magnesium, this being a substance everywhere easily obtainable, and possessing moreover a high actinic value (b). In the cases in which our object was to obtain records of the condition of the pupils after some minutes exposure of the eye to complete darkness, the burning of magnesium ribbon was obviously useless. The methods of taking instantaneous photographs by magnesium flash-light are essentially two, viz., (1) that in which pure magnesium, in a finely powdered form, is blown suddenly through a flame, (2) that in which an explosive mixture is used.

To begin with, we used the first of these methods, employing the "Todd-Forrett" apparatus supplied by Mr Baird, Lothian Street, Edinburgh. The first experiments made with this method convinced us that, however suitable for its own particular purpose, this apparatus was quite useless for our experiments, where, if I may so express it, the absolute negation of light previous to the bright flash is a conditio sine quâ non. When the lights are turned off in an ordinary photographic "dark-room," it wants a very few seconds for the retina to accustom itself to the altered circumstances, and to begin to discover various spots and streaks of light where their presence before was never suspected. The result of this is that a reflex contraction of the sphincter pupillae follows, and, the eye being suddenly thereafter illuminated by a flash, the resulting photograph shows a pupil only moderately dilated. This being the result of attempting to get the widest dilatation of the pupil in any room in which a very special care has not been taken to eliminate the faintest traces of light, it follows a fortiori, that in any apparatus of the first class, in which a perfectly visible though faint light is burning previous to the flash, the resulting photographs are quite unsatisfactory.

It having been found impossible to absolutely screen this "preliminary" light, I next turned my attention to the second class of flash-light apparatus - that by "explosive mixture," in which no "preliminary" light is employed at all.

Fig. 2.

Of various mixtures which I tried, that which gave the best results was the "Flash-Light Bayer"; this, besides giving a very bright flash, has the additional advantage over other mixtures of producing very little smoke - a consideration by no means to be despised when the operator is working in a room in which the necessity for total abolition of light interferes considerably with the ventilation.

This "Bayer" mixture can be exploded in various ways: in the apparatus which I used, the release of a trigger strikes a match, and simultaneously plunges it into the mixture.

Fig. 2 is a characteristic example of the results obtained: a reflection of the flash is seen on the left side of the pupil, and a comparison of its position here with that in the other photographs will roughly indicate the lateral distance from the eye at which the flash was discharged: thus, if we compare it with Fig. 14, we find that in the latter the reflection appears very nearly in the centre of the pupil, the aim having in that case been to shine as bright a light as possible upon the retina, and thereby exert a maximal effect upon the mydriasis from which the patient was suffering. (Fig. 14 was actually taken by 6 seconds exposure to burning magnesium wire).

Fig. 3.

Fig. 4.

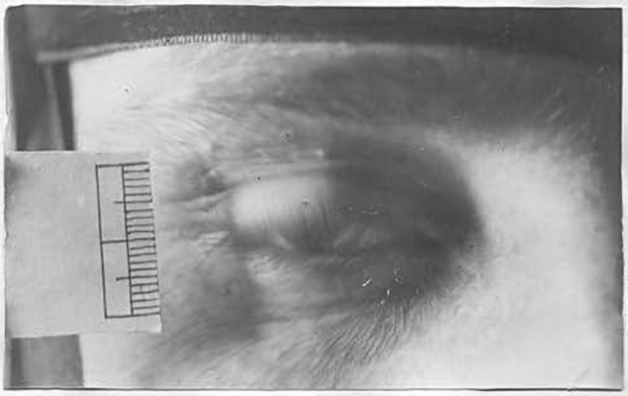

Fig. 5.

Fig. 6.

As regards results, it may be not without interest first of all to illustrate some of the difficulties which arose during the taking of the annexed examples.

It sometimes happened, for instance, that the flash occurred during the act of winking, with the result that the pupil was more or less obscured in the photograph. Figs. 3, 4, 5, and 6 are examples of this difficulty, and may serve to illustrate four consecutive stages in the act of winking. It is noteworthy, however, that in by far the larger number of cases the eye appeared normally open, the flash being too rapid to provoke the nictitating, as the pupillary reflex, before the photograph was taken: it was only necessary to tell the sitter to "keep his eyes open", after which, if a wink occurred it was rather by inadvertence than as a reflex after the flash. At the beginning I asked the sitter to hold his eye open with his fingers in each case, but soon found that this was quite as unnecessary as it was irksome.

The photographs taken by Du Bois-Reymond to illustrate full dilatation were given a quarter-of-an-hour's rest in darkness previous to the flash (c). I allowed the same time in my experiments, but,

Fig. 7 (7 mm.).

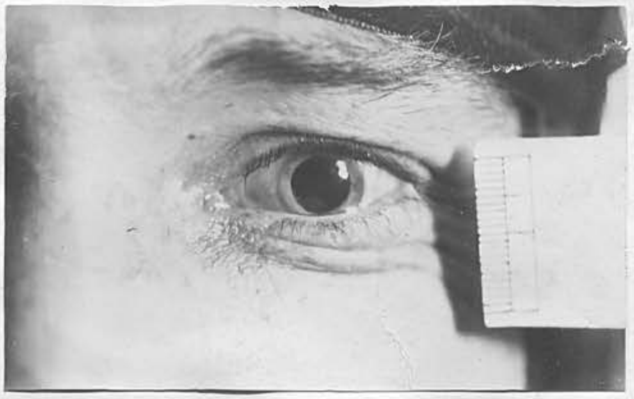

Fig. 8 (7.5 mm.).

Fig. 9 (8 mm.).

Fig. 10 (4 mm.).

besides this, I took the same eyes after only two minutes' rest. The results proved that the latter period is hardly enough to allow of the extremest possible dilatation of the pupil, as I found, on an average, that there was from .5 mm. to 1 mm. of difference in size of a pupil taken after the two different periods of rest, the average breadth in the horizontal meridian being 8 mm. after the long rest, and just over 7 mm. after the shorter period: in some cases the pupil was as large after 2 as after 15 minutes, but, as I have said, the average of a considerable number of photographs of normal eyes showed close upon 1 mm. of difference.

Figs. 7 and 8 show the same eye after, respectively, 2 minutes and 15 minutes' rest in darkness; they illustrate well the difference in dilatation which I have mentioned.

The other method which I employed, - namely that of exposure of the eye to burning magnesium ribbon - may be here referred to. In this case the sitter is directed to look straight into the flame, in order that the light may fall on the macula lutea and produce the strongest effect. Figs. 9 and 10 show the same eye photographed by the two different methods: in Fig. 10, which was taken by 6 secs. exposure to burning magnesium

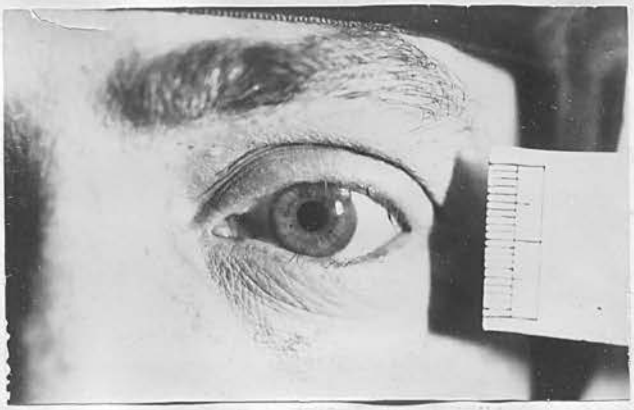

Fig. 11 (4 mm.).

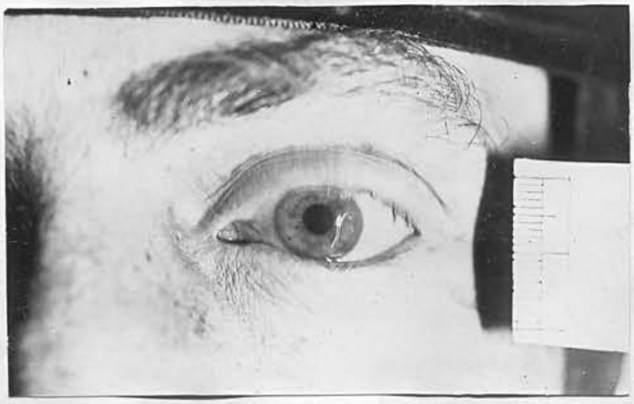

Fig. 12 (4 mm.).

Fig. 13 (8 mm.).

Fig. 14 (6.8 mm.).

ribbon, it will be observed that the corneal reflection of the flame falls approximately in the centre of the pupil.

It is interesting to compare with these photographs showing the limits of contraction and dilatation in a normal pupil, some pathological conditions in which the pupil is less mobile. Take for instance Figs. 11 and 12, both of the same eye: the subject of the photograph was suffering from tabetic spinal myosis, as well as partial optic atrophy, and the pupil was almost completely unaffected by light; thus Fig. 11 was taken by the usual flash-light method, after 15 minutes' rest in darkness, while Fig. 12 was the result of 6 secs. exposure to the bright flare of the magnesium ribbon: the absolutely rigid pupil neither expanded in darkness, nor contracted to the slightest degree in response to light; it will be observed, however, that in Fig. 12 the pupil is at least contracted very nearly as much as the normal pupil in Fig. 10, taken under the same conditions: the specially abnormal point, therefore, brought out by this pair of photographs is the failure of the pupil to dilate when all sources of light are cut off.

Again, in Figs. 13 and 14 we have the interesting condition of traumatic mydriasis; observe that

Fig. 15 (6 mm.).

Fig. 16 (5.8 mm.).

Fig. 17 (8 mm.).

Fig. 18 (2.5 mm.).

Fig. 19 (8.5 mm.).

in Fig. 14, though the patient was looking directly into the burning ribbon, the transverse measurement of the pupil does not stand below 6.6 mm. (compare with the healthy pupil in Fig. 10 for contrast). Fig. 13 represents this mydriatic pupil taken after the usual 15 minutes in darkness; the size assumed in daylight was something between that in Fig. 13 and that in Fig. 14.

It is known that the pupil is usually not so large in hypermetropia as in the normal or emmetropic condition. Figs. 15 and 16 are of an eye of 3 dioptres hypermetropia, both taken after the long exposure to darkness. The contrast of these with such an eye as that in Fig. 17, taken under the same conditions, is striking.

Finally I show two photographs of an eye, in both of which the sitter was made to look for 6 secs. directly into the flame of the burning magnesium ribbon: in Fig. 18 the eye was in the normal condition, while in Fig. 19 it was atropinised, and remained perfectly unaffected by the light; the contrast between the two results could hardly be more marked.

As regards the action of atropine, it is worth recalling here that the dilatation produced by it is much greater than that brought about by section of the third nerve (d); in explanation of this it has been suggested that atropine also acts by irritating the terminal fibres of the sympathetic. In complete darkness, too, the widely dilated pupil affords considerable contrast with the medium dilatation obtained by section of the oculomotor (e). The problem of the actual mechanism involved in the production of these phenomena might well be elucidated by the aid of some photographic method, such as the one I have described.

The above photographs are given merely in order to suggest some of the possibilities of that method, and are not intended to be in any way exhaustive.

It has seemed to me that, besides being suitable for employment in the clearing-up of certain problems in eye-physiology, an apparatus of this kind might have its use in the ordinary routine of hospital ward-work, being adapted for securing records of the condition of the pupil, especially in cases of disease of the nervous system.

Naturally the method is only applicable in the case of patients who are not too ill to sit up, but, by some simple modification it could no doubt be made suitable for photographing the pupils of bedridden patients as well. Such photographs would dispense with the need for, and would illustrate the actual pathological conditions much more strikingly than any verbal description.

In conclusion, I have to express my indebtedness, first to Dr Arthur Sinclair for much kind advice, and secondly to Dr J. Bartholemew Mears for his ready help in the more purely technical part of the experiments. To Dr Claude du Bois-Reymond, the pioneer in this branch of photographic work, I am indebted for courteously giving me information as to his personal contribution to, and experience with the subject.

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(d) Tscherning, "Optique physiologique", p. 193.

(e) ibid, p. 195.