ON SOME PECULIARITIES CONNECTED WITH RETINAL IMAGES.

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IN the 'Nineteenth Century' for October last, I detailed at considerable length some experiments I had been making in connection with the phenomena of after-images. It is not desirable to repeat my description of the experiments here. Those who are interested in the subject will have no difficulty in referring to them in the magazine in question. I wish, however, to recapitulate a few main points, by way of introduction to some physiological facts which will probably prove of more immediate interest to the readers of 'BRAIN.'

The main conclusions at which I arrived, after devoting several months to careful experiments, are the following:

1. That the colour of an after-image produced by gazing steadily at bright light or a strongly illuminated surface, such as white paper in sunlight, is not in any way dependent on the colour of the object we look at, but upon the amount of light thrown on the retina; either by the greater or lesser intensity of light in the object itself, or by the amount of time during which one looks at it.

2. That the succession of colours the image undergoes in forming and fading follows the order of the colours of the solar spectrum.

3. That the image is intermittent if the exciting object is looked at with one eye only, and intermittent in colour if it is looked at for a certain interval with one eye, and then for a similar interval with both.

These, briefly stated, are the main results of my observations. With reference to the first point, I may add that the best after-images are produced by placing a half-sheet of white note-

paper in sunlight, and then fixing the gaze with absolute steadiness on a small pencil-mark in the centre. If the sun is shining brightly, and I look at a paper thus exposed for ten seconds and then close and cover the eyes, I get a blue after-image. If I look for fifteen seconds, I get a green image. If I look for twenty-five seconds, I get a yellow image; but no amount of exposure ever produces any colour beyond the yellow. With reference to the second point, if the eyes are kept closed, the colour of the image changes first to dull orange, then to pink, then to crimson, then to violet, and, after an interval, back to blue; thus, as I have before observed, following the order of the colours of the solar spectrum. After the image returns to blue, it darkens and fades altogether.

With regard to the third point, namely the intermission of the image if looked at with one eye only—which fact seems to be considered the most valuable discovery from a physiological and probably from a pathological point of view—I would remark that various experiments have led me to the conclusion that, *under certain circumstances*, one eye, if rigidly fixed, is incapable of a sustained impression of vision. The reasons among others, which have induced this belief are the following :

If I fix one eye on a certain point in the sky—a small white immovable cloud is the best object—and then close and cover the other eye with the hand, in about half a minute or a minute, if the eye is kept very steadily fixed, a dark cloud like London smoke comes over the point at which I am gazing, and entirely blots it out. After an interval of a few seconds the cloud reappears, and again, after an interval, disappears.

If I look at a sheet of paper in sunlight with one eye for some twenty seconds and then close and cover the eye, I get a coloured after-image which comes and goes at intervals of six or seven seconds. This image, I should remark, is not nearly so vivid as the images formed by looking with both eyes, and it is much longer in forming.

If I look at a white object through a glass of a certain colour with one eye and through a glass of another colour with the other eye at the same time, the colours do not mingle, but the object appears first of one colour and then of the other,

alternating at intervals of a few seconds. This last experiment has been dealt with at some length by Helmholtz, but the former ones I have never seen recorded.

It appears to me that the explanation of the intermission lies in the close sympathy which exists between the two eyes, from the peculiar manner in which the optic nerves unite and again divide. Each must necessarily partake, to some extent, of the sensation conveyed to the other. For instance, after gazing at the white cloud for a certain time and receiving the impression of light in one eye, the darkness of the closed eye begins to assert itself, and insists on conveying the sensation of darkness to the sensorium before the eye exposed to light is again allowed to convey its impulse of light.

Since the publication of the article to which I have referred, I have discovered a few new facts in connection with the sensation of colour which seem to me of considerable interest. I must, however, admit that one of these is to some extent antagonistic to some theories I before advanced. In connection with the resources of the retina, I ventured to raise some objection to the "fatigue theory," so popular with Helmholtz and other physiologists. My idea was that the phenomena connected with this theory were due rather to a principle of compensation. The fatigue theory is founded chiefly on the fact, that if we look at a particular colour for a certain interval, and then remove the eyes to some plain surface, we see the complementary colour. I urged that this could hardly arise from fatigue, because if we continued looking at the original colour, although it might become less vivid, it never wholly disappeared. It appeared to me that, if it arose from actual fatigue of the rods and cones, which seem to be the seat of the primary sensation of vision, we should after a time fail to appreciate the colour altogether. This I now find, under certain circumstances, is actually the case. The simple experiment which led to my discovering this is, I think, new, and may excite some interest. It is of course known that if the three primary colours, or all the colours of the solar spectrum are painted on a disk, and the disk is made to revolve rapidly, the colours disappear and the disk assumes a greyish-white tint. I was anxious to ascertain if the sensation

of white could also be obtained by prolonged exposure of the retina to the three primaries without the revolving process. I therefore coloured a piece of cardboard with faint tints of the three primaries accepted by artists, namely red, blue, and yellow, painting these colours in stripes of equal width. I then held the card in the sunlight, fixing my eyes upon a pencil mark in the centre. In a few seconds the colours began to grow fainter, then to merge into each other, then to disappear altogether, and it appeared to me as if I were holding a piece of white card in my hand. If, however, I moved the eyes to ever so small an extent, either to the right or left, so as to bring the different tints on to another part of the retina, they immediately reappeared, and were apparently intensified in tone. This experiment seemed to me a conclusive proof that if the three rays from the three primaries were conveyed to the retina simultaneously, the sensation of white was produced, thus, apparently, at the same time proving that red, blue and yellow were the primary constituents of white light.

I next proceeded to experiment with the three colours accepted by Dr. Thomas Young, Professor Helmholtz, and other physiologists, as the primaries, namely red, green, and violet; painting faint tints of each on a card in the same manner as before. Somewhat to my surprise the result was precisely the same. When held in sunlight, the colours disappeared if the eyes were immovably fixed on them. This led me to think that it must be something apart from the combination of particular rays which produced the sensation of white. I therefore tried the experiment with two colours. Again the result was the same. I then isolated the centre colours of the first card, by covering the other two colours with white cards. The result was still the same. The colour disappeared, and the three cards presented an almost uniform surface of white. I was thus forced to the conclusion, that it was not the combination of certain coloured rays which produced the sensation of white, but that the retina was incapable of sustaining the impression of strongly illuminated faint colours on the same portion of its surface for any length of time. As I have before remarked, if the gaze was shifted to ever so slight an extent, the colour at once reappeared; which

fact leads me to the conclusion that it is only by the rapid and constant shifting of the eye that we retain the full sensation of colour. There have been so few recorded observations of the results obtained by fixing the eyes immovably on strongly illuminated objects, that this class of experiments seems to me to open quite a new field of investigation. The disappearance of the colours came upon me as a new and most surprising fact, and certainly does favour the theory of fatigue.¹ I should mention that the same effect may be produced, to a certain extent, by strong gaslight or ordinary daylight, but the result is not nearly so satisfactory.

I am anxious to record another very curious fact in connection with the intermission of the image before referred to. I happened to be looking at the sun through my telescope one morning, for the purpose of observing some sun-spots. On withdrawing my eye from the telescope, and turning towards a dark corner of the room, I found that I had a pink after-image of the sun. Remembering that it was the result of looking with one eye only, I anticipated the intermission, and found that it almost immediately commenced. I then took a rapid glance at the sun with both eyes, and then closed and covered them. The result was very curious. The intermittent after-image first produced was still coming and going at intervals of a few seconds, and through this intermittent image was seen the non-intermittent after-image produced by the momentary glance with both eyes. It should be borne in mind that the first image, having been obtained through the telescope, was magnified some eighty diameters, so that the second image was only seen as a small spot in its midst, but still it was seen in the *same field*, and therefore presents a most curious illustration of the extraordinary and complex powers and capabilities of the retina--the power to retain two distinct impressions of the same object upon the same spot.

Dr. Crichton-Browne seems to be under the impression, that in my former paper I did not make sufficient allowance for the personal factor. He considered that I possessed a special

¹ Since this was written, Dr. Tuke has sent me a paper by an American writer which induces me to think that these effects are produced by changes in the visual purple.

faculty for the production of after-images. This idea, however, is not borne out in my experiments with others. When the conditions are the same, the results have been almost identical, even with those who have experimented under my directions for the first time. Almost all the experiments, described both here and elsewhere, have been tried with others, and generally with the same results. I have no doubt, however, that the faculty of observing after-images may be greatly increased by cultivation. It is evident that the retina is never wholly at rest. Even in the middle of the darkest nights, in bed, with the eyes closed, one is conscious of certain colours passing in waves across the retina, and of flashes and rings of light resulting from sudden movements of the head. One very curious and very constant sensation is that of certain concentric rings, or waves of colour, which appear to flow from the outer circumference of the retina towards a variable disk of colours in the centre, generally of a crimson or purple tint. I have no reason, however, to suppose that even this sensation is abnormal.