statements on stabilisation, are, in their uncertainty and unproved state, very open to attack. But still more so is the case with the opposite doctrine of the "school myopia." It is not only unproved, but one can bring weighty facts against it; as an example I refer to research on twins. There is, therefore, much to be said for the view that consequences of practical importance should not follow the doctrine of the school myopia, and restrictions in the near work of the young myopic patient should not be made.

Summary

Steiger's doctrine of the origin of refraction is enlarged with the conception of stabilisation.

Stabilisation is the cessation of the growing of the eye; its term varies with individuals. It plays a rôle equal to the combination and variation of the optical elements in the formation of the definitive refraction, and it is equally an inherited quality. The cause of the higher degrees of myopia is interpreted as retarded stabilisation.

The two weak points of Steiger's doctrine, the excess and the asymmetry of the variation-curve, are explained by the biological peculiarities of stabilisation.

A detailed knowledge of stabilisation will enable us to foretell the future of an early myopia.

Near work has nothing to do with the development of individual myopia, therefore restrictions in reading and studying by the young myopic patient should be put aside.

PIGMENT-ANOMALOSCOPY: A NEW PROCEDURE FOR TESTING THE COLOUR-SENSE*

BY

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AS is known there has been up to now one method that enabled us not only to test but to measure the colour-sense in some degree: the mixing of spectral lights, as realised practically in Nagel's anomaloscope. Theory and knowledge of colour-sense and colour-blindness have been exclusively based on results obtained in this way.

The colours we see and discriminate throughout life differ from spectral lights; in opposition to the latter we call these "pigment-colours."

The important physical difference between the two forms is

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well known: the spectral-colour has one wave-length or is built up at most of a very short section of the spectrum. The pigment-colour on the other hand includes all wave-lengths of the half of the colour-circle, thus being sometimes more than the half of the spectrum (*W. Ostwald's doctrine of the "colour-half"*).

It is less well known that the physical difference becomes sometimes manifest in the sensual perception also. These are, for example, the rules of colour-mixing, with considerable divergence between spectral and pigment colours. From our standpoint there is the important fact that persons with defective colour-vision react differently sometimes, depending on whether the colours are spectral lights or pigments (Nagel, Rosmanit, Köllner). In practice it is not a rare occurrence that a deuteranomalous person makes mistakes with Nagel's anomaloscope and not with the pseudoisochromatic tables; or that a protanomalous sets a normal or almost normal Rayleigh-equation, and shows on the other hand great irresolution in the pigment-tests. It was because of this that some authors would have banished the anomaloscope from the current testing methods of colour-vision as misleading.

The question is far from being cleared up. To get some insight into the problem, the first task would be to construct an instrument by which we would be able to mix measured pigment-colours as we do with Nagel's anomaloscope.

The production of such an instrument is possible since W. Ostwald has succeeded in building up his colour-body, representing in it all pigment-colours well defined and exactly measurable. Though the polemics about the scientific value of the colour-body have not been settled definitely, its great practical value is beyond question. To the ophthalmologist who tests colour vision it is a help, and in the future it will probably enable us to penetrate more deeply into some of the unsolved questions of the colour-sense.

We have only to produce an instrument that mixes defined and measured pigment-colours additively and allows these two mixtures to be compared simultaneously, as is done in Nagel's anomaloscope with spectral colours.

The rotating disc, this well-known expedient of additive mixing, is not applicable for our purposes. Instead, we have to take cylinders which, rotating around their axes, mix the colours of their surfaces as well as the disc. This has been done. We took two parallel cylinders side by side, that could be pushed independently of each other to and fro during rotation. There were some technical details to solve, but we had at last the necessary construction, the "pigment-anomaloscope," fully coming up to our expectations. It proved shortly to be a useful and readily applicable instrument for testing and studying colour-vision.

FIG. 1.

The pigment-anomaloscope uncovered.

FIG. 2.

Pigment-anomaloscope covered, showing the observation slit.

The model we have been using is reproduced in Figs. 1 and 2. It is a simple artisan-made piece, but shows all the important features. It works alternately either by hand or by electricity. The two cylinders glide on steel axes and are changeable. On their surfaces are the colours to be mixed, on detachable papers. These are, of course, carefully selected and determined according to Ostwald's colour-body. For example, there are "8 na" red and "20 na" green on the one cylinder

FIG. 3.

The surface of the cylinder with the two colours to be mixed, showing simultaneously the middle.

and "a" white and "p" black on the other, this being the basic pigment-mixture of red-green, matched with neutral grey.

The surface of the cylinder is a parallelogram, it is diagonally divided for the two colours. In order to get a more perfect mixture the surface can be sub-divided into narrower parallelograms (Fig. 3).

We see on the left end of the lower rotating cylinder pure red, on the right end pure green. Towards the middle both colours are getting more and more greyish, till in the middle they meet in a small stripe of neutral grey. On the upper cylinder there is a continuous change of grey from black to white. Both cylinders are covered with a black metal plate with a linear slit in it (Fig. 2). The examinee sees only as much of the cylinders as appears in this stenopæic opening.

Both rotating cylinders can be pushed to right and left by handles. Simultaneously with the two handles there are two indicators moving on tape-measures, showing the position of each cylinder. The zero indicates that the middle of the cylinders are in the slit.

When the apparatus is in gear, the examinee has nothing else to do but to push both cylinders to right and left till he sees in the slit above as well as below the same colour, neutral grey. In this position the indicator of the lower cylinder shows the amount of red and green necessary to obtain the match. In a normal trichromatic case this is fifty-fifty, the indicator should point to zero, or be very near to it. That adjustment corresponds fully with the normal Rayleigh equation.

The protanomalous requires more red, the deuteranomalous more green. In matching, the indicator stands somewhere on the right or left side of the tape-measure, showing the necessary amount of the colours. To make a record we have only to note the side of the tape-measure (f.i. D or P), and the figure at which the indicator points. For example, "D 34" indicates that the examinee found equality on the green side of the cylinder, 34 mm. from the centre, hence took 67 per cent. green and 33 per cent. red instead of 50-50 of the normal.

To register the grey cylinder is commonly superfluous, as it has only a theoretical value. We use it in practice only to give the examinee a grey to be matched.

There is a parallel between the recording of our instrument and Nagel's anomaloscope. The zero of the latter (that is the equation of the normal) is usually between 50 and 60 (mostly at 54). Higher figures denote protanomaly, lower ones deuteranomaly. We could as well put zero in the place of 54, in which case the records of both anomaloscopes might obtain the same meaning (except the fundamental difference). On that account Nagel's anomaloscope is well replaced by our instrument.

But it is more than a simple supplement, as it completes Nagel's anomaloscope in many respects. These are some of them:

(1) The cylinders being changeable, all imaginable mixtures are easily effected. Out of these the yellow-blue mixture has a practical value in two directions: it is a test for exposing simulation, and we might find by its help the rare condition of tritanomaly.

(2) Comparing the results obtained on both anomaloscopes, we are able to get some insight into the question of the difference between the perception of the same colour whether of the spectral or of pigment variety. The direct comparison of the results has been made possible by the well-known quotient of v. Kries (Q), deduced from the relation

$$Q = \frac{\text{green}}{\text{red}} (\text{normal}) : \frac{\text{green}}{\text{red}} (\text{examinee}),$$

green and red meaning the amount of colours in per cent. used to obtain neutral grey.

The examinee being normal, the Q has to be necessarily 1. In the very same manner the Q of a protanope has to be more, of a deuteranope less than 1. The great value of the quotient consists in eliminating all differences that arise out of the differently constructed and adjusted types of anomaloscopes. Thus the quotient gives a generally valid character of a person's red-green perception. If there were a discordance between the spectral and pigment quotient of the same person, an explanation could be found only in a difference between the perception of the spectral light and pigment colour. We found such cases sometimes in our investigations. There is, for example, the analysis of the following case:

On Nagel's anomaloscope a deuteranomalous examinee sets the equation at 30. The drum of our anomaloscope is divided into 88 lines. The normal equation is at 54, hence the first fraction of v. Kries' quotient is $34/54$. The fraction of the examinee being $58/30$, the spectral quotient is found to be 0.32.

The cylinder of the pigment-anomaloscope has a length of 200 mm. and a circumference of 100 mm. The zero being in the middle, the normal equation is $50/50$. At 100 mm. it is from 50 to 100 per cent. of colour, we obtain the numerator of the division by adding to 50 half the number set by the examinee. The number completing this sum to 100 is the denominator.

The same deuteranomalous patient found neutral grey on the pigment-anomaloscope at D 32, hence the division of the quotient is $66/34$. The quotient itself is 0.51.

We see there is a difference of 0.19 between the spectral and the pigment quotient. We may conclude that the perception of green has been 19 per cent. better when presented in pigment form. The examinee passed the pseudo-isochromatic tests faultlessly. This fact seems to confirm our conclusion.

(3) The pigment-anomaloscope is well applied to determine the threshold of the colour-stimulus—a new possibility. In practice there did not exist such a method. It has not only theoretical interest but it makes a welcome completion of the colour-sense tests.

We have only to put the colour on to the cylinder in the shape of a triangle, the two supplementary colours on the two ends of the cylinder, and interpolate white triangles (Fig. 4), the latter serving to eliminate the disturbing influence of the light-sense.

The examinee has to find the inner borders of the coloured impression. Starting from the middle, he sees only a change into grey in the beginning. He stops as soon as he has recognized a coloured impression. Of course, we do not obtain an absolute value, but in equal circumstances a comparable value.

FIG. 4.
Arrangement of the colours for threshold examination.

Anomalous trichromats always display such an increase of the threshold that it alone is sufficient to reveal their anomaly. We find generally an increase on both sides, yet protanomaly shows a greater increase in red, deuteranomaly in green, following the theory of Young-Helmholtz.

With the aid of threshold-investigations perhaps we shall be able to penetrate deeper into some hitherto obscure problems of the colour-sense. There is, for example, the question of Wölflin's "relative red- and relative green-sightedness," also the normal varieties type I and type II of Tschermak-Seysenegg, all probably associated with threshold differences.

There are the rare but interesting cases of colour-weakness with a normal equation (Edridge-Green). In such cases we could suppose an equally increased threshold for both complementary colours; of course, investigations in this direction are still lacking.

(4) Finally it may be mentioned that we are able to reproduce every continuous colour-band in a simple way on the pigment-anomaloscope, and also the spectrum. Naturally they are composed only of "colour-halves," nevertheless they show every peculiarity of the original in the sensual perception and are therefore applicable.

Conclusion

I have tried to show that the pigment-anomaloscope would make a useful completion of colour-testing. It could even enlarge our knowledge of colour-vision. The model reproduced in Figs. 1 and 2 is, of course, in many respects rough;

made by a skilful mechanic it could take the form of a faultless, silently running and exact instrument. It could even be further improved for scientific purposes. It would be necessary, for example, to make its illumination independent of daylight; to narrow the field of observation to points and to bring them together into one round divided surface, observed through a telescope, similar to that of Nagel's anomaloscope. For the present I had to content myself with the model at hand.

A NEW METHOD OF APPLYING THE SCREEN TEST FOR INTER-OCULAR MUSCLE BALANCE

BY

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THE apparatus described in this communication was developed at the Manchester Royal Eye Hospital as the result of a series of experiments designed to overcome certain difficulties experienced in the application of the Hess screen test.

In the Hess method, a colour separation system is used to obtain dissociation of binocular vision, and the difficulties experienced were all attributed to this. Such a system, whilst theoretically capable of perfect results, is apt to be inefficient in practice, because of the difficulty of manufacturing materials of the exact and stable colours required for the screen, pointer, and goggles. Even if initially correct, these are likely to deteriorate with age and use. If the colours of the components used are not exactly correct, the dissociation obtained is only of relative degree, and errors then are liable to occur in the test. Thus the red pattern of the screen may be faintly visible through the green glass, or the green pointer through the red glass. The resultant accuracy of the test depends on the brightness of these images compared to the correct ones.

If the secondary image allows of unocular localization of the pointer to the cardinal points through either glass, the test is rendered useless; or even if the position of the green pointer is seen through the green glass, and related, as it should be, to the apparent position of the red cardinal points seen through the red glass, still the result may be inaccurate, owing to the fusional stimulus caused by the screen pattern being visible, to a greater