A Confusion-Test for Colour-Blindness.

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The work described in this paper was done in conjunction with Lieut.-Col. W. R. L. Scott, late of the 62nd Foot, who was very nearly, but not quite, red-blind. He could not under ordinary circumstances distinguish the red coat of a soldier from the black coat of the civilian, though on closer inspection it seemed "not so good a black." His colour-sensations are given in my paper on "Artificial Temporary Colour-Blindness."*

He continued to take an active interest in the subject, and gave me a good deal of help from time to time in testing the colour-sensations of other people, in which he was very successful, his own colour-blindness enabling him to win their confidence. It had been intended that his name should appear as joint-author of this paper, but he died on April 9, 1911, aged 78.

In the summer of 1903 we arranged to collaborate in painting a series of test-cards, accurately adjusted to his colour-sensations, oil-colours being selected, as easier of manipulation than water-colours, and less likely to fade.

I. For the first, I painted the half of an Academy board, 9 inches by 7, with two coats of vermilion, using very little medium and painting as solidly as possible. When this was dry, several different kinds of green were mixed, spread on strips of wood, and held near the red background, the most satisfactory being selected by Lieut.-Col. Scott, who indicated which of the colours on the palette might improve it. This I tried until he expressed himself completely satisfied with the match. My function was to make the colours as unlike as possible to normal eyes, and his to make them match perfectly to the red-blind. The other half of the board was then painted with the mixture, which was about the colour of a year-old ivy leaf, and it was allowed a fortnight in which to dry and also to see if any change of colour occurred on drying.

I then painted, in his absence, on the green part of the card the words DON'T GO, the letters N'T being in vermilion and the rest in blue. The blue he could see immediately—in fact there seems to have been to him as much difference between green and blue as there is to us between red and green. But he read the inscription as DO GO, being absolutely unable to distinguish the letters in vermilion. After a while, by holding the panel sideways, so as to get the light on the brush-marks, he managed to decipher them, but he could see no difference in colour. In order to prevent the

* 'Phil. Trans.,' B, vol. 191, p. 29.

brush-marks from being seen, I devised the plan which constitutes the novelty of this test.

The card lies at the bottom of a box like that of an old-fashioned stereoscope, but larger. In front of the card, at a distance of 6 or 8 inches from it, I fix a sheet of perforated zinc, and the observer looks through a short tube in the top of the box, containing a convex lens of about 8 diopters, focussed on the zinc. The card is so far beyond the zinc that it is necessarily out of focus, even for those possessing full power of accommodation, all that can be seen through the holes being merely the colours, which form a mosaic of coloured dots, not unlike those of Prof. Stilling's test, from which, in fact, I got the idea.

But the method has this advantage over Stilling's cards—given the colours, any design can be painted in a few minutes. It is astonishing how soon the exact description of a test-card becomes known if many people from the same neighbourhood are tested; hence the importance, even in the absence of any conscious attempt to deceive the examiner, of being able to vary the lettering.

A year later, Lieut.-Col. Scott said that the colours were no longer a match, and he could even read the red letters through the perforated zinc. On close inspection there appeared to be a sort of whitish bloom on the surface of the vermilion, but so very slight that few people would have noticed it. He found that fresh vermilion still matched the green, as did the old after the application of oil. From this it would appear that the green was unchanged. The whitish bloom would represent to him an addition of blue, to which he was exceedingly sensitive.

II. For the next card the pigment selected was geranium-red, which differs from vermilion by the addition of blue and violet, these colours being distinct to Lieut.-Col. Scott. This was found to match with a sort of French grey or slate-colour with no tendency to green. On the grey half of the card I painted GO in blue and NOT in geranium. The first word he could see at a glance, but the second was invisible to him, although to me it was more conspicuous than the other.

III. For the third card we took emerald green, mixed with a little yellow, to cut off some of the blue rays. This was found to match with a rather rich yellow ochre, made with Mars yellow, Oxford ochre, and a little burnt sienna. The letters P.T.O. were painted in the yellow ochre mixture on the green, and R.S.V.P. in emerald green upon the yellow ochre background.

He could not see either, the whole card appearing one uniform green to him. But he immediately detected the letters O.K. upon the green and A.B.C. and Z upon the yellow ochre in a salmon-pink made by adding a very little geranium-red to the yellow ochre, instead of the burnt sienna.

IV. For a fourth card we made a full-toned lilac with mauve, magenta and zinc white. The colour by which this was matched was a fairly pure blue quite free from any tint of purple, but showing in the spectroscope a good deal of green. On the lilac half I painted P.K.W. in blue, and on the blue half the letters X and I in a slightly paler blue, made by mixing a very little more zinc white with the ground colour. The difference is so slight that very few people can trace these letters through the perforated zinc, although they see the letters P.K.W. immediately.

Lieut.-Col. Scott, on the other hand, could not detect P.K.W. and the whole card appeared of one uniform bright blue tint to him, but he instantly perceived the letters X and I. I have noticed this same sensitiveness to depth of colour in other cases of red-blindness.

Complete or nearly complete red-blindness is immediately detected by these cards. Partial cases can sometimes read the letters, but do so with difficulty. Green-blind people easily read the first three, but are stopped by the fourth, being unable to distinguish between lilac and the greenish blue.

The apparatus has been in use in Oxford for colour-testing ever since we made it, and answers admirably. We found that the X and I on No. IV were easily visible to all the cases of red-blindness, but not to the green-blind nor the normal.

With regard to the permanence of the colours, we found in 1908, *i.e.* after five years, some slight changes had taken place in all but No. I, which had not altered after being oiled. In No. II the geranium had lost something of its blue and violet components, and in No. III the yellow mixed with the emerald green had faded, so that Lieut.-Col. Scott, who knew what to look for, could just make out the lettering. But other colour-blind people were still deceived and No. IV was as effective as ever with both the red- and the green-blind.

All test-cards, especially such as Nagel's and Stilling's, are liable to deteriorate, but the use of the perforated zinc enables fresh designs to be prepared with so little trouble that this objection is easily remedied in our test-cards. It is much to be desired that some one who is green-blind, or has otherwise abnormal colour-sensation, would prepare a set of cards with as much care and accuracy as Lieut.-Col. Scott did these for red-blindness.

Most of the testing was done in the Physiological Laboratory, Oxford, some in University College, Reading, and some were cases from the Oxford Eye Hospital. The expenses, which were trifling, were defrayed out of the Government Grant Fund.