Tests in Common Use for the Diagnosis of Colour Defect*

By Dr. Mary Collins

THE testing of colour-blindness in all its forms presents a problem of great practical importance involving the adoption of a definite technique.

The spectrometer is undoubtedly the most fundamental test of colour vision, but it is seldom available for practical purposes, and the majority of tests, apart from those in scientific laboratories, are carried out either with some kind of lantern test or some kind of pigment test. There are various types of lantern tests available. The Edridge-Green colour perception lantern is the only one which has been used by the writer. A newer model is the Board of Trade lantern test, recommended with modifications by the committee set up to consider colour vision requirements in the Royal Navy. In using this the eyes have to be dark-adapted for 15 minutes. The Giles-Archer perception unit is also a new and simple model, and it, too, requires the eyes to be dark-adapted. These lantern tests, and many others, have the advantage that coloured lights are used instead of pigments, which brings conditions of testing nearer to everyday conditions in the Services, the railroad, navigation and aviation.

Certain pigment tests have also been extensively used, and it is these I should like to discuss in some detail. In some of these tests, it is puzzling to find mistakes made sometimes by individuals with normal colour vision which should only be made by colour-blinds. The printing of the tests may be partially to blame, but it must be recalled that decisions are constantly being made on the results from these tests, and therefore it is essential to recognize which responses are diagnostic and which can be ignored. In order to reach a valid basis for diagnosis, I have given a battery of tests under constant conditions of distance and illumination to an unselected group of about 340 candidates, exclusive of colour-blinds, applying to be accepted as apprentice printers. Their responses, therefore, to the tests may be compared with the responses of a group of colour-blinds tested under the same conditions. This normal group acts as a control group against which the results for each test used can be evaluated at its proper worth.

Owing to exigencies of space it will not be possible to discuss the details of the results obtained with all the tests which have been used. I can indicate the type of investigation under progress by giving the results from one of the tests only, "The Ishihara Tests for Colour Blindness" (5th Edition).

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The Ishihara test is composed of a number of pseudo-isochromatic plates in which coloured numerals appear on coloured backgrounds. In some of the plates only part of a numeral appears to a person who is colour-blind, this being dependent on the colours used. For example, an 8 may be the numeral read by one with normal colour vision, but only part of it may be seen by the colour-blind, and he reads it as 3. Or a totally different numeral may be seen by the colour-blind from the arrangements of the spots before him, and instead of seeing a 5 as the majority would do, he sees a 2 standing out distinctly from the background. Further, in some plates, the position is reversed as it were, and although the person with normal colour vision sees nothing but a blur of colour, the colour-blind sees a numeral quite clearly. If one with normal colour vision looks at these plates through a blue glass, the 'hidden' numbers become visible.

The individuals forming the control group who were tested were found to vary markedly in their colour discrimination. It seemed advisable to divide them into two groups termed respectively N (normal) and $N-$ (showing greater deviation from the normal). The classification is of necessity an arbitrary one because it is difficult to know where to draw the dividing line ; in fact, the line of demarcation between colour-blinds and non-colour-blinds may itself vary according to the purpose in hand. In the report of the "Colour Vision Requirements in the Royal Navy", already referred to, it is stated of a certain test that if used alone it causes extravagant rejection of candidates who may be fit even for the seaman branch. This merely indicates that the standard for rejection can be changed in accordance with the post to be filled. It is interesting to note that three grades, so far as colour discrimination is concerned, are suggested in this report.

The colour-blinds in the present test have been classified thus because of their responses not to any single test but to at least six tests, and in some cases a spectrometric examination was also made. Similarly, in the N and $N-$ groups, their allocation to these classes is based on the results obtained from the same battery of tests.

The accompanying table shows the results from the Ishihara test when given to these three groups. The percentage frequency of the responses in each group has been calculated with regard to normal responses and colour-blind responses. The table

is read thus: in plate 5, 56 per cent of group *N* read the figures correctly as the normal do, that is, read them as 74, whereas 11 per cent of group *N* read the figures as the colour-blinds do, that is, read them as 21. The frequency of responses other than normal and colour-blind has been omitted. In the *N*− group, 29 per cent gave the normal response, 31 per cent the colour-blind response. In the colour-blind group, 0 per cent gave the normal response, 81 per cent gave the colour-blind response.

ISHIHARA TEST.

Frequency in percentages of normal and colour-blind responses for *N*, *N*−, and colour-blind groups.

Plates	As read by normal	As read by *C.-B.*	Normal *N.*	Normal *C.-B.*	*N*− *N.*	*N*− *C.-B.*	Colour-Blind *N.*	Colour-Blind *C.-B.*
1	12	12	100	0	100	0	100	0
2	8	3	100	0	100	0	40	55
3	6	5	100	0	100	0	21	71
4	5	2	99	5	92	4	12	74
5	74	21	56	11	29	31	0	81
6	2	—	99	0	83	1	0	100
7	6	—	100	0	96	4	5	95
8	5	—	100	0	98	2	5	95
9	7	—	100	0	100	0	2	98
10	—	5	91	4	89	6	0	95
11	—	2	72	27	48	48	0	100
12	26	2 or 6	99	0	90	1	5	59 10
13	42	4 or 2	100	0	100	0	10	55 26

The frequency of responses other than normal and colour-blind has been omitted.
N = 286 males: *N*− = 48 males: *C.-B.* = 45 males.

Plates 2 and 3 are never wrongly read by either the *N* or *N*− group, but Plate 3 seems the better diagnostic test of colour-blindness, as 71 per cent of the colour-blinds failed on it, and only 21 per cent passed. Plate 4 is equally good, although 0·5 per cent of the *N* group and 4 per cent of the *N*− group gave the typical colour-blind responses. Plate 5, which is read as 74 by the normal and as 21 by the colour-blind, is said by Miles to be "certainly the most sensitive indicator of colour weakness that we possess", and in the summary at the conclusion of the article, he suggests that in testing men for mercantile establishments only Plate 5 need be used at the original interview. It is also regarded in the "Report on Colour Vision Requirements in the Royal Navy" as one of the most searching plates. It is true that 81 per cent of the colour-blind read the figures as 21, and the others in different erroneous ways, but if we look at the results from the *N* and the *N*− groups, we must modify our opinion. Only 56 per cent of the *N* group passed, whereas 11 per cent failed, that is, read the 74 as 21. The remainder read the 7 as a 2 or as a 9 or as a 1, so that the figures read as 24 (7 per cent), or 94 (2 per cent), or 14 (1 per cent): or the 4 was read as a 1, and the numbers read as 71 (20 per cent), or 91 (2 per cent) or 11 (1 per cent). In the *N*− group, the percentage of those passing is even smaller, 29 per cent, and the failures 31 per cent. The other variations also occurred. It may be, of course, that this plate offers a very delicate test of colour weakness, and therefore is very effective in picking out colour defect of varying degree. But sometimes it was the only error the individual made not only in this test but also in a group of tests.

The next four plates seem to be very significant. The normal group shows a perfect pass in all four and the colour-blinds almost a complete failure.

The next two plates containing the hidden numbers differ very much as regards efficacy for detection. The hidden 5 is certainly not visible to the normal eye, and the fact that 4 per cent with normal colour vision saw it easily is a curious result. These 4 per cent have perfect colour vision on all the tests, and one would be almost inclined to rate them as *N*+. Whether the supersensitive see the 5 or not requires further investigation. The 2, on the other hand, is not satisfactory. It could be seen fairly easily by all groups, as will be evident from the percentages quoted. Twenty-seven per cent of the *N* group and 48 per cent of the *N*− group were able to read it.

The last two plates are very satisfactory.

The Ishihara test is a very reliable test of colour-blindness and did not allow any of the colour-blinds to pass. It also seems to detect colour weakness in a highly efficient manner.

The results from this test may be sufficient to give some idea of the type of investigation which has been carried out. A similar analysis of the results obtained with other pigment tests—the Stilling, Schaaff's mosaic plates, the Nagel, the Podesta, the Edridge-Green, etc., leads to similar conclusions, namely, differences in the value of individual tests, inconsistencies in the findings arrived at with any single series, and so on.

There is a good deal of doubt whether we ought to speak of reliability and consistency in connexion with the results of this analysis. It may be that the discrepancies disclosed are due to the great variety of those deviations from normal colour vision which are so marked as to justify their being regarded from a practical point of view as cases of colour-blindness. This interpretation of the facts is to some extent confirmed by the results of filter analysis. Plates which all profess to diagnose deuteranopia, for example, show very differently under filter analysis, and similarly evoke different responses from different deuteranopes. The inference would appear to be that we are dealing not with linear variations in degree but with multidimensional variations. A wide new field for investigation is thus disclosed, the working of which may yield valuable results for the whole theory of colour vision.