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THE
DETECTION OF COLOUR-BLINDNESS,

From a Practical Point of View.

BY

F. W. EDRIDGE-GREEN, M.D.,

B.S., M.R.C.S., L.R.C.P.,

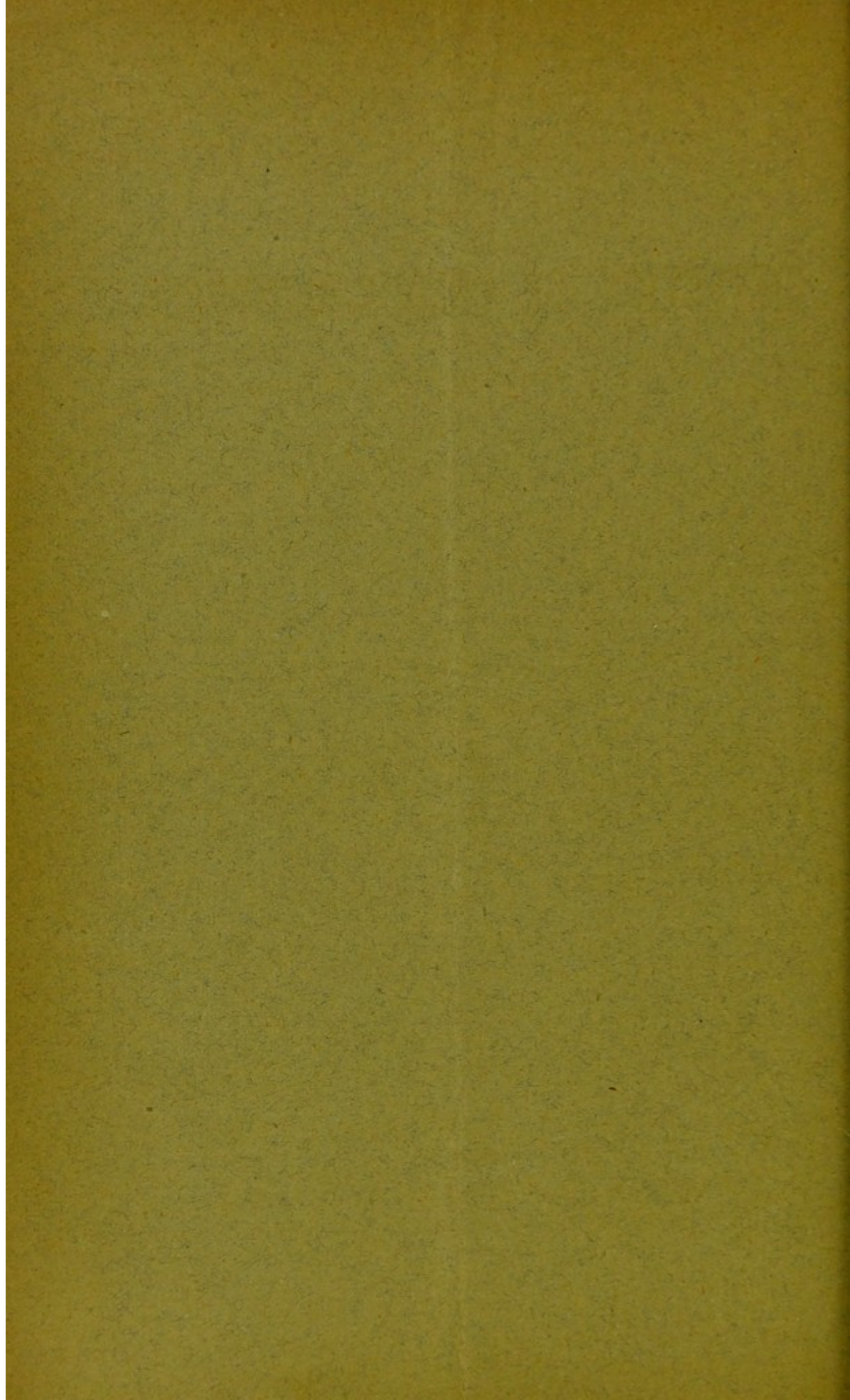
*Author of "Memory: its Logical Relations and Cultivation," Member
of the International Code of Signals Committee, &c.*

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THE DETECTION OF COLOUR-BLINDNESS.

I HAVE written this pamphlet in answer to the numerous requests for information concerning the tests which I recommend for the detection of colour-blindness. As I intend to issue a book on the subject within the next year I shall, in the following pages, confine myself almost entirely to the practical aspect of colour-blindness. Those who may wish to consider the theory of colour-perception which I have advanced, I may refer to my book on "Memory," p. 43 *et seq.* and *Medical Press and Circular*, April 3 and July 17, 1889.

Another point which has had considerable weight with me in publishing this pamphlet, is the really deplorable state of affairs with regard to testing for colour-blindness on the British railways. The subject has been taken up in a very commendable manner by the *Railway Press*, the editor of which has issued a circular to the managers of the different railway companies, requesting for information concerning the methods employed for testing for colour-blindness. In the majority of instances a reply has been sent, giving details of the tests used. The answers are published in full in the *Railway Press*, September and October, 1889, and are well worth perusal.

I will not give the tests used by any particular railway company, as the worthlessness of the majority will be obvious to most members of the medical profession, on perusal of the above-mentioned replies. It would be interesting to find out what idea of colour-blindness the inventors of some of these tests had. I should have

thought that the fallacies of some of them would have been obvious to a child. Such a test, for instance, as that consisting of three or four colours painted on a board in a definite position. The inventor does not seem to have thought that a normal-sighted person may have told the candidate the position and names of the colours.

I am sure that more attention would be paid to the subject if the public appreciated what colour-blindness is. No intelligent man could object to persons, who cannot see any difference between the colour of a scarlet coat and that of the grass, and cannot distinguish between the red and green lights at a distance of 100 yards, being excluded from services in which it is necessary to readily distinguish between those colours.

Testing for colour-blindness is not an easy matter, even with the most efficient of tests, considerable experience being required to make a competent examiner. Without an efficient test, no amount of experience will be of use.

The subject is of such importance that I am surprised that more attention has not been paid to it from a practical point of view. With the methods which are in vogue at the present time there is no guarantee that the examiner himself is not colour-blind.

I wonder how many of the 1,400 collisions at sea, which occurred during the year ending June, 1888, were due to colour-blindness of the navigating officers. It is terrible to think that railway accidents and collisions at sea should occur through laxity in testing those whose duty it is to distinguish between the coloured lights. Shall we wait until some great railway accident draws universal attention to the subject, and the worthlessness of the tests in use, before those tests are changed? I would not travel by a train if I knew that the engine-driver was colour-blind.

With regard to the persons who should conduct the examination for colour-blindness: there seems to me no doubt that the testing should be conducted by a medical man, specially trained in colour-blindness. I must say again, most emphatically, that it is useless for a person who is not acquainted with the phenomena of colour-blindness to test for the presence of this defect. In the following pages I have, for the benefit of those who have not been personally instructed by me, given the common errors which the examiner is liable to fall into. But the cases

of colour-blindness vary in so many particulars that considerable experience will be required before an examiner is competent to pass or reject candidates for the marine or railway services.

The nature of the test has nothing to do with this, the facts are there and only require to be detected. It is as useless to set an inexperienced person to test for colour-blindness as it is to ask a student who has only a rudimentary knowledge of the use of the ophthalmoscope to diagnose some retinal affection from a description in a book.

It must be remembered that a colour-blind person has never seen colours as the normal-sighted see them, and therefore is not acquainted with the nature of his defect. We have equally to test stupid as well as very shrewd persons.

A few words on my theory of colour-perception will be necessary for a proper appreciation of the following tests. It is a theory essentially based on the perception of differences in a physical series. A normal-sighted person can see six distinct colours in the spectrum, that is to say, six points at each of which there is a distinct difference. Then as each of the colours at these points must, by the connection of other points, pass gradually into each other, we have modifications of each of these colours or units. An absolute psycho-physical colour unit is a portion of the spectrum which appears monochromatic. The approximate psycho-physical colour units are the number of distinct colours seen, and these are the most important, and are the only ones which it is necessary to pay attention to, because if the absolute psycho-physical units increase in size, it follows as a matter of course that the approximate psycho-physical units must diminish in number, the length of the spectrum remaining the same. The spectrum may also be shortened at either the red or the violet end, but this may occur without diminution in the number of units, and *vice versâ*.

This theory is supported in every particular by the examination of 101 cases of colour-blindness. The following tests are based on the facts obtained from these examinations.

The colour-blind may, therefore, be divided into two classes :—

I. Those who whilst having a spectrum of the normal length have a diminished number of units, that is to say, they see five, four, three, two or one colour instead of the normal six.

II. Those who with or without the normal number of units have a spectrum shortened at one or both ends.

From a practical point of view we wish to devise a test which will show whether the examinee will be able to distinguish between the standard red, green and white lights under the conditions in which he is likely to be placed. We do not wish to exclude the five or four unit colour-blind, or persons who have the violet end of the spectrum shortened, or the red end only to a slight degree. These persons are able to distinguish between the coloured lights as easily as a normal-sighted person can, and, therefore, though scientifically they are of great interest, for all practical purposes they are normal-sighted. We wish to exclude from the marine and railway services all those individuals who are included in the following three classes:—

I. Those who possess a psycho-physical colour perception with three or less units.

II. Those who, whilst being able to perceive a greater number of units than three, have the red end of the spectrum shortened to a degree incompatible with their recognition of a red light at a moderate distance.

III. Those who are affected with central scotoma for red or green.

I will now explain why these three classes of persons should be excluded.

With regard to the first class. This class includes the three-unit, the two-unit and the one-unit, in accordance with my examinations of the colour-blind with the spectrum. The three-unit, instead of seeing six colours in the spectrum see only three, the two-unit two, and the one-unit one. The three-unit never, under ordinary circumstances, mistake green for red, but confuse green, purple and gray. Colour is a very feeble quality of objects to them, and nervousness or excitement may reduce them to the condition of the two unit colour-blind.

The two-unit regard green and red as almost but not quite identical, and this fact is one which it is nearly impossible to make a person, who has not thoroughly studied colour-blindness, comprehend, either the colour-

blind himself, the public, or an unqualified examiner. They find that many colour-blind are able to recognise different colours and correctly name them, and therefore set down the mistakes made to want of education in colours. We cannot wonder at these comments, considering that the large majority of recorded cases have been of school children and uneducated persons. This source of error I eliminated by using for my standard cases only educated adults who had tried to train their colour sense, and were well aware of the names of colours. The following will show how it is that the colour-blind are able, under ordinary circumstances, to distinguish between the colours included in one of their units. All colours have not a similar degree of luminosity; thus yellow is much the brightest colour. To the two unit colour-blind, red, yellow and green have, as far as colour is concerned, a very similar appearance. They are not exactly alike in colour because they are included in an approximate, not in an absolute, psycho-physical unit. Green looks a lighter and grayer colour than red. A normal-sighted person might be given a bundle of wools, consisting of three kinds, the first, different tints of yellow, the second, tints of yellow mixed with gray, the third, shades of yellow, that is, yellow mixed with black. He would be able to arrange these in three groups with few mistakes.

With regard to class two. It is very important that persons belonging to this class should be excluded, and yet none of the ordinarily used tests detect them. The rays of red at the extreme left of the spectrum are the most penetrating, as may be seen by looking at a light or the sun on a foggy day, or through several thicknesses of neutral glass. It is chiefly by these rays that we recognise a red light at a distance, and it is therefore of great importance that a sailor or engineer should be able to perceive them.

With regard to class three. This condition is one in which a person might be able to distinguish colours easily when they are close to him, but fail to distinguish them at a distance owing to the nerve fibres supplying the central portion of his retina being impaired. As a light at a distance occupies the central portion of the visual field, it is essential that the corresponding portion of the retina should be normal.

We also do not wish to exclude persons who, though

partially colour-blind, have a colour perception sufficient for all practical purposes.

With regard to the test to be used. If the persons to be tested have to distinguish between the standard red, green and white lights, these lights should be used as the basis of the test, because if any other test were used we should still have the same problem before us from a practical point of view. A sailor might (with reason) object to any other test, and say that because he cannot distinguish between a green and a gray wool it is no reason why he should be unable to distinguish between the red and green lights.

By using a lantern with slides containing standard red and green glass, we can obtain the necessary colours. But there are few colour-blind who cannot distinguish between the red and blue-green lights at a short distance. A simile will show how they are able to do this. If a normal-sighted person were to take two coloured glasses, green and blue-green, and place them in the lantern, at a short distance, he would be easily able to distinguish between them. He would see as much difference between them as the colour-blind (two-unit) do between the standard red and green. But as the distance became greater he would find more and more difficulty in distinguishing between them, and it would be very unsafe to trust a ship or a train to his powers, especially when one light only was shown. The two unit colour-blind find the same difficulty with the standard red and green. The intensity and character of the light should therefore be changed without the knowledge of the candidate. This may be done effectually with certain kinds of neutral glass.

The glasses I use, like a mist or fog, are most transparent to the red rays at the extreme left of the spectrum, and when several glasses are used together the light allowed to pass through them has a distinctly reddish hue. The normal-sighted easily recognise coloured lights that have had their intensity diminished by neutral glass, but the colour-blind find great difficulty in distinguishing the colours under these circumstances.

The apparatus of the test, therefore, consists of a lantern, slides containing the standard red and green, pure green, blue, purple, and yellow glass. Four slides containing neutral glass of the requisite character, of

different degrees of thickness, one slide containing ground white glass and another containing ribbed white glass. The pure green, purple, blue, and yellow slides are necessary to prevent guessing on the part of the candidate. The testing should be done in a dark room, the examinee being seated opposite the lantern and at a distance of about fifteen feet from it.

The examiner should on no account conduct the examination on any regular plan, because the candidate, anxious to pass, finds out from persons who have already passed the order and method of the examination, and so, though colour-blind, might obtain a certificate. Any one of the slides may be first shown, and the candidate required to name the colour of the light.

The following will serve as an example of the method to be employed in testing a candidate. The standard red slide being placed in the lantern, the candidate is required to name its colour. Then a blue or a green slide may be substituted. Then one of the neutral, ground or ribbed glass slides should be inserted, not the slightest intimation being given to the candidate of the nature of the slide. He should be asked to name or describe the light, and the answer, if incorrect, together with his other replies, carefully recorded. The other slides may then be shown, a combination of the neutral, ground, ribbed and coloured glasses being used at irregular intervals. Care must be taken when the candidate is going to be examined with two slides at once, such as one of the neutral, ground or ribbed glasses and a coloured glass, that he does not see the light until both slides have been inserted, or else he may see the colour before it is modified in the necessary way.

Another practical point to be borne in mind is that the modifying glass should be placed in *front* of the coloured glass and not between it and the light, just as the fog or mist is in front of the signal glass and not behind it.

If the candidate call the standard red, green, or the standard green, red, under any circumstances, that is, either alone or in combination with the modifying glasses, he is to be rejected.

The examination may cease when a candidate has mistaken green for red, or *vice versa*. He may be convinced of his incapacity by seeing the colour he has mistaken close to and unmodified.

Particular attention should be paid to the answers given to the combination of the thickest neutral glass with the standard red and green respectively. This glass is of such a thickness that it obstructs all light with the exception of a band of red at the extreme left of the spectrum and a band of green.

This glass, when used in combination with the standard red, gives a red light visible to the normal-sighted at a considerable distance. With the colour-blind if the red end of the spectrum be much shortened the red light will not be perceived at all.

The glass in combination with the standard green gives a dull green light which is easily recognised by the normal-sighted.

It will be noticed that with this glass the relative intensity and character of the red and green lights are changed. With the unmodified lights the green is lighter and bluer than the red. When modified with this neutral glass the green appears the darker and yellower of the two, exactly as it does in a mist or fog. The two unit colour-blind, therefore, at once call this combination red, because the colour is made to look so much like their red. I have not met with a two unit colour-blind who has named this combination correctly; the answer has invariably been "red" usually with some positive exclamation, as "There is no doubt about that being red" or "black." The importance of this fact cannot be over-estimated, because I have tested educated colour-blind persons who have found no difficulty in naming the colours when unmodified with neutral glasses—and so would have obtained a certificate. These would be most dangerous persons at sea, because they would deliberately mistake the red light for the green and *vice versâ*. At the same time they would feel positive about the nature of the lights. It seems to me that in all probability this is how many accidents have occurred.

If the candidate call the white light, under any circumstances, red or green, or *vice versâ*, he is to be rejected. Also if he call the red, green or white light, black under any circumstances.

As it is the confusion of red, green and white which forms ground for rejection, in examining with the neutral glasses the examiner should be guided by this point. Thus a neutral glass may give a reddish tinge to the light; a

candidate calling the light red might be reconsidered, whilst a candidate calling the light green would be rejected without further consideration.

One incorrect answer (embodying one of the mistakes mentioned above) suffices for rejection. This is important and must be strictly adhered to. A normal-sighted person would not mistake the colours confused by the colour-blind. Colour ignorance is quite as fatal (if the mistake were due to this cause) as colour-blindness; thus if a sailor on seeing a red light *thought* it was a green one, and steered as directed for a green light, he would cause an accident just as surely as if he were colour-blind.

A candidate who has made one mistake only may be passed on to a specialist, but should never be passed by an examiner not thoroughly acquainted with all the theoretical and practical details of colour-blindness. An examiner should as far as possible avoid all conversation with the candidate, simply asking, "What colour is this?" and recording the answer without comment. If an examiner after each answer say "Quite right," or some such expression, the following is likely to occur. The candidate, after say six correct answers, makes a mistake; the examiner says "Are you sure?" Then the candidate knows at once that he has made a mistake and makes a guess, very probably a correct one. When a similar colour is shown subsequently he remembers the mistake he made and gives the second and probably the correct answer.

Mistakes other than those mentioned above simply demand a very searching examination.

On re-considering this test we find that it is not open to any objections. The material is the best possible, as it will not fade like all dyed substances, and therefore all records made with one set of apparatus will be uniform. Again, a coloured light has none of the accessory qualities which enable the colour-blind to pass through other tests. Thus many two unit colour-blind will call the yellow glass red or green, who would not think of putting a yellow with a green or red wool, on account of the difference in luminosity. The test is not open to any of the objections which may be urged against the method of simply naming colours, because the character and intensity of the colour may be changed at will.

No amount of coaching will enable a colour-blind to pass this test, whilst almost any other may be passed in this way.

The test also has a quality possessed by no other, namely, that of enabling the examiner to reject dangerous persons, and dangerous persons only, the lower degrees of colour-blindness being allowed to pass.

With regard to other tests for colour-blindness. In conformity with the theory of psycho-physical perception I have had a pocket colour test made by Curry and Paxton, which answers admirably for all ordinary purposes. It consists of 112 single threads of wool, 13 pieces of twisted silk, 9 small pieces of cardboard, 3 pieces of changeable silk ribbon, and one piece of green velvet. These (with the exception of the end threads of each row) are numbered consecutively. The end threads of the first four rows are numbered from I. to VIII. in Roman figures, and form the tests; they are orange, violet, red, blue-green, rose, pure green, yellow-green, and electric blue. The changeable silks change very considerably when taken from daylight to gaslight, the most marked change being from bright green to purple. The series of colours I have selected and arranged so as to confuse the colour-blind and force them to be guided by their colour perception, whilst the quantity of colour is amply sufficient for the normal-sighted to pick out the colours with the greatest ease.

The two most important test colours are the orange and violet, Nos. I. and II. The person examined should be asked to pick out the shades of colour similar to No. I. (orange). If he do this correctly he probably possesses normal colour perception. If, however, he match the test with reds or pinks, and plainly finds difficulty with the colour, he is more or less colour-blind, at best belonging to the five-unit class. If in addition he match the violet test No. II. with blue, he at least belongs to the four-unit class. The three unit colour-blind, in addition, matches the blue-green test, No. IV., with purple, blue, rose, and grey, and puts yellow with the orange. The two unit colour-blind matches the red test, No. III., with green. Other mistakes will be made: thus the two-unit will match the orange test, No. I., with yellow-green and yellow-brown, but the above are the diagnostic signs for each class. Most of the varieties of the colour-blind will be readily detected in this way. The other four tests are confirmatory and elucidatory, modifications occurring on account of shortening of the spectrum and the presence of a neutral band.

The above-mentioned pocket test is useless for the purpose of testing sailors and engineers, for the obvious reason that the colours are fixed, and therefore a candidate could buy a test and study it with the aid of a normal-sighted person.

I have therefore made a series of separate colours on the same plan, and called it the "Classification Test for Colour-Blindness." The test colours are the same as those used in the Pocket Test, namely, Orange, Violet, Red, and Blue-green. These are labelled I., II., III., and IV. respectively. The box contains a series of colours chosen by me, and are those which are especially confounded with the test colours—150 wools, 10 skeins of silk, 10 pieces of coloured cardboard, and 10 pieces of coloured glass. Printed directions are pasted to the lid of each box. As in the Pocket Test the candidate is told to match the test colours.

The Lantern Test is an absolute necessity, and the Classification Test cannot be substituted for it. It will be found advantageous to have the latter test for use in cases in which the examiner finds difficulty in making up his mind as to the rejection of a candidate. The use of this test will also enable the examiner to become familiar with the mistakes made by the colour-blind.

Nearly all the tests in use at the present time are based on the Young-Helmholtz theory of colour perception, and only repeat the fallacies of this theory. With regard to Holmgren's wool test. It presents the manifest objection which all tests which have not coloured lights as the basis are open to, namely, that it has to be proved that a man who puts a confusion colour with a green wool cannot distinguish between a red and a green light. Then, when the man has put a confusion colour with a green wool, there is still the point to be decided whether he has been judging more by shade than by colour. In my experience an ignorant four unit colour-blind is more likely to fail than an educated two-unit. Many colour-blind can escape detection by this method, who would be dangerous as sailors or signalmen. For instance, a person might have very considerable shortening of the red end of the spectrum and not be detected. Also many three-unit can pass, and also those with central scotoma for red or green. Another great objection to the wool test is that duplicate colours are not obtained

with certainty, because colours which appear similar have not necessarily the same composition. Indeed, some of the features of this test are due to the use of impure colours. The red test skein (II. *b*), in both the Holmgren sets which I have obtained from Berlin, reflects a large quantity of violet light. The skein appears to differ very little from a pure red to the normal-sighted, but seen through a blue-green glass it appears violet, whilst a pure red appears black. This makes very little difference in testing an ordinary case of red-green blindness, because the preponderance of red rays causes the colour to fall into the red psycho-physical unit. But the presence of the violet rays causes the colour to be perceived as red, mixed with a large amount of grey, because a mixture of violet and red appears grey to the two-unit. The green, therefore, that he matches with this colour will be a blue-green containing similar proportions from each unit. The red (III.) in my Pocket and Classification Tests is a much purer red, and the two-unit, therefore, match it with bright yellowish greens (78 and 94), instead of the dull greens represented by 10 and 12 in Holmgren's plate.

Then, if the red end of the spectrum be much shortened, the red test (II. *b*) will not be classed with reds, but with blues, as happened to me in one case. The reason of this is, that as a considerable number of the red rays are not perceived, they have to be subtracted from the composition of the colour. The violet rays predominating causes the colour to fall into the violet psycho-physical unit.

There can be no division into red and green blind. If any two unit colour-blind be set to classify a large number of colours, he will make the mistakes of both classes.

It is difficult to say who should be excluded by Holmgren's test; if we exclude only the completely red-green blind, we shall allow persons who are dangerous to officiate as signalmen. If we exclude all the partially colour-blind, we shall exclude many who are competent to act.

Then, the fading of the wools has to be taken into account. Another objection is that the greens which it is necessary to pick out will become more soiled than the others, and so afford a mark of distinction to the colour-blind, who, not being confused by the striking differences of colour, are able to notice minutiae of this kind. Holmgren himself relates a case of a man who could dis-

tinguish between brown and green by the touch, but not by the colour.

Again, many colour-blind persons will pick out a large number of green wools leaving one or two in the pile. An inexperienced examiner may at once pass the candidate. Should he not do so, he is placed in an awkward situation if the candidate refuse to pick out any more wools, saying there are no more like the test green. He has put no confusion colours with the test green, but only greens. Holmgren suggests that, under these circumstances, the examiner should take one of the greens which has been overlooked, and one of the confusion colours, and ask the candidate which two out of the three are the most alike. I contend that this is not a fair way of examining, because the answer to the question so much depends upon the point of view from which the wools are regarded, namely, which is the examinee likely to be influenced by—the shade or the colour. Uneducated persons always find a difficulty in matching shades of colour, and they will often answer, “Neither is much like the test.” Under any circumstances, an uneducated and unpractised colour-blind is under a disadvantage compared with an individual who is educated and practised in colours.

A pure green is one of the worst possible colours to choose for a first test, because, in the five, four and three-unit, the green is simply enlarged. Therefore, if the blue-greens be removed, these colour-blind may easily pass through the test without detection.

Twin Colours.—Stilling's plates, Cohn's worsted letters, Donder's discs, and Grossman's method are included under this head.

The method of employing twin colours is useless, because there are different degrees of colour-blindness. Thus dealing only with the two-unit, we may have a spectrum of normal length, or the red or violet end may be shortened in a variable degree. If, for instance, we had twin letters of red and green made with colours selected by a two-unit with an unshortened spectrum, on examining a two-unit with considerable shortening of the red end of the spectrum we find that he can read the letters with the greatest ease, because the red portion (on account of a large number of rays not being perceived) would appear much darker than the green. In the same way combina-

tions which do not contain red are rendered useless by the presence of a neutral band or shortening of the violet end of the spectrum. In addition there are the minor objections, of the colours having different degrees of luminosity, arrangement of threads, &c. Stilling's lithographed plates have the additional objection of having the twin colours overlapping the ground.

Tests in which the Complementary Colour has a part.—Shadows coloured by contrast, Cohn's chromasciopticon, Waldstein's chromatoscope, and Phlüger's letters come under this head.

Tests of this description have very little value; they are more likely to detect the ignorant than the colour-blind. The colour-sense is diminished in the colour-blind, but not to such a degree as to prevent them from seeing complementary colours if means be taken to make these vivid.

If a pure red glass be used, the complementary will be blue-green. The colour will be exactly the same for the colour-blind. I have tested many colour-blind with coloured glass, making them look through the glass for a minute or two and then at a piece of white paper, and required them to pick out a colour in my Pocket Test corresponding to that of the complementary seen. They have in each case picked out a colour very similar to that of the complementary seen by me. If the Young-Helmholtz theory were true, the two-unit, if they saw a complementary of red at all, would see it as blue, whereas they see it as a colour which corresponds to their sensation of green.

The conditions of light and the purity of the colours are also points which would have to be taken into consideration.

The above are the only tests worth mentioning, and the fallacies of those which I have not discussed will be obvious from the remarks which I have made.

All my Colour Tests can be obtained from Messrs. Curry and Paxton, Opticians, 195, Great Portland Street, W.