11. Precautions to be taken by the Engineering Department when repairing the track, etc.

12. Instructions for working inclined railways and train working on steep gradients.

13. Hand-signaling.

The idea being to reproduce, as far as possible, actual working conditions, a model section of railway was installed, consisting of a double-track junction, with full equipment of side track, switches and signals such as are usually found at a typical junction station. The signaling is in accordance with the latest British practice, as laid down in the regulations of the Board of Trade, every feature—such as interlocking, slots, electric repeaters, ground discs, etc.—being reproduced in miniature. The signal box has a frame containing 25 levers, while working in connection with it are disc block telegraph instruments representing adjacent block posts on the main and branch tracks.

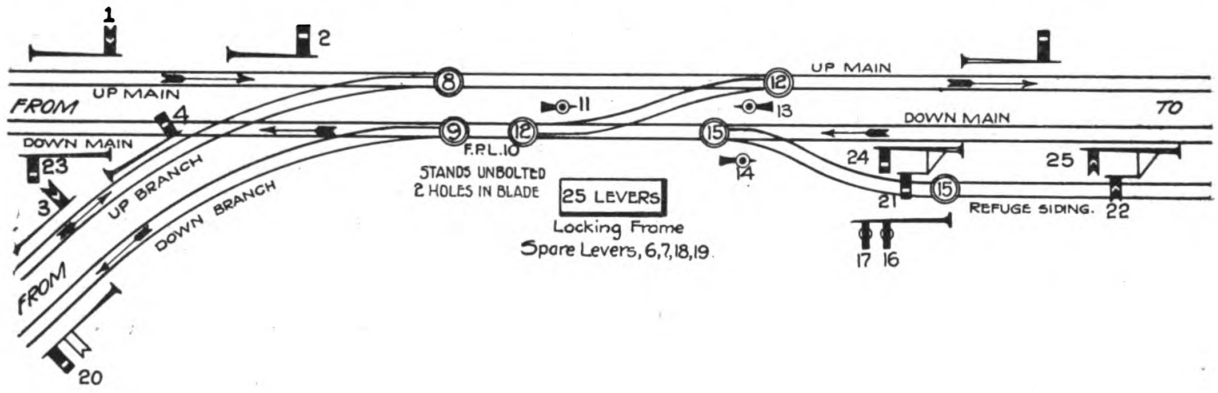
The text books are the company's book of Rules and Regulations and the appendix to that book containing in detail the regulations for operating the railway. A course of instruction embraces from fifteen to twenty lectures, and a class is limited to some twenty-five students. Following each lecture a discussion takes place, and the students are required to perform various operations with the aid of the model. Lectures are given weekly during the autumn and winter months, and at the close of a course students may undergo an examination, on the result of which certificates are awarded by the company, the possession of which is specially noted in the recipient's official history and secure for him special consideration in regard to future promotion.

We understand that the experiment has been so successful that classes have been established in various centers throughout the Great Western system. In each case special care is taken to ensure that the lecturer is a fully competent official, while the course of instruction is regularized by the circulation from headquarters of skeleton lectures, indicating exactly what points are to be specially dealt with.

A further development in the matter of staff instruction has lately been made by the formation of classes in railway station accounts and the office work connected with transportation business. In this case also examinations are held and certificates awarded to successful students.

The underlying motive actuating the company is, we understand, to afford all members of the staff, no matter in what department employed, the means of becoming acquainted with the general principles of railway working and business. As a result, several promising men have been "discovered," whose capabilities were such as to render them of more use to their employers in other departments than those in which they were formerly employed.

The lectures in no way compete with outside educational agencies or the university courses to which we have already referred; and while it may be contended that lecturing and teaching in the manner described are the special functions of the scholastic profession, the arrangement undoubtedly has the advantage of securing lecturers who are always up-to-date in regard to the rules and regulations of their own railway, in which respect the system has much to commend it.



Color Sense and Railway Signal Lights *

In the discussions which have been taking place since the introduction of the new method for testing color sense, the opinion has often been expressed that the exclusion of persons with abnormal trichromic sight from the railway and marine service is an unnecessarily harsh measure; this objection I myself have heard made, and it is also to be found in technical publications. Some persons indeed, who it is true, are mostly not medical men, even go so far as to doubt the danger of employing persons with dichromic sight in the railway and marine service.

The interest thus shown in the practical importance of congenital color-blindness, which during the last twenty years was disregarded or but little considered, can only be received with pleasure, even if we are unable to agree with the opinions expressed. Although I have quite recently explained the most important reasons which induced me to desire to include persons with abnormal trichromic sight among "color-incapables," yet I propose to add further information on the subject, information which may tend to convince some of those who were hitherto opposed to my opinion. It mainly concerns a series of trials, made before and reported by the Berlin directorate of the Prussian Street Railway and the medical department of the ministry of war and the navy department.

What I particularly desire is that my colleagues who have officially to test the color sense of persons according to my system, should not only do so because they have instructions to that effect, but also because they recognize the necessity of the new prin-

*Paper by Professor W. A. Nagel, in Zeitschrift für Sinnesphysiologie, translated and republished in the Bulletin of the International Railway Congress.

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ciples; with this obpect in view, I have made new trials with improved apparatus and have had the results properly recorded and controlled. I venture to hope that these results will convince the skeptics of the "color-incapacity" of those with abnormal sight, let alone the total uselessness, for the railway and marine service, of those with dichromic sight.

The objections against the exclusion of those with dichromic sight and (more recently) of those with abnormal trichromic sight, are based on two alleged facts: 1st, that no accidents on railways or at sea have been caused by them; 2nd, that those persons who were declared to be color-blind when examined by the usual tests proved to be perfectly capable of distinguishing colors as required when tested "on the spot," i. e. with actual railway and ship signals.

The first argument I will not consider here; I will merely refer the reader to my remarks on this point in the Zeitschrift für Sinnesphysiologie, volume 41, part 4, where I explain why it is only possible in very few cases to prove with certainty that a given accident has been the result of defective color-sense, while nevertheless color-blindness is not really so harmless as some people might think.

The second argument deserves a little more consideration, especially as it is the one more particularly raised again and again by those chiefly concerned. namely by those in the railway or marine service. Typical, and quite intelligible from the point of view of its author, is the remark made in an article about the testing of the color-sense in the German nautical publication Hansa, September, 1906, No. 39. There it is stated: "A university professor of Rostock, ophthalmologist and member of the commission for secondary examinations, was in the habit of giving sailors. who could not distinguish with certainty red and green skeins of wool, but could distinguish red and green ship lanterns, a certificate that they could distinguish colors well enough, and of telling them: 'just quietly continue to be a sailor, but do not become a wool merchant!'"

The impression which such a remark (its authenticity is hardly open to doubt) by an "expert," or still worse by a superior eye-examiner, is likely to make on sailors must be considerable. It certainly appears to many laymen, and also to not a few technicians, to be the most natural thing to test the color-sense of the applicant as employee in question by means of those lights, which he will have to distinguish in the course of his employment, that is to say, by means of signal lanterns and signals, which are the same as or similar to those actually used. The only difficulty is that the tests should be carried out under the same conditions as occur in actual practice. Let us consider these conditions a little more closely.

1. Let us assume that a man of average intelligence and acuteness of vision, who wishes to enter the railway service and who with a view to the color-sense tests has often carefully looked at railway signals, is tested by being shown in succession a number of red and green railway signal lights, burning brightly, at a distance of 100 metres (110 yds.), the changes of color being made in an irregular series. Then the probability that the man tested will make an error is exceedingly small, even if he is color-blind or has an abnormal color-sense. I would hardly expect one mistake to a hundred questions.

2. Let us assume that another man has the same intelligence and acuteness of vision as our first man, but has never had anything to do with railway or signal lights; then if he is unexpectedly tested in the same way as in case 1, the probability is already considerable that he will make errors, if he is color-blind or has an abnormal color-sense; he may describe the red as yellow, or the green as white, yellow or blue. If a hundred questions were asked, there would be a considerable probability that several mistakes would occur, particularly during the earlier questions. Practice and knowledge of the colors used in the tests are therefore of much importance if such an examination is to be passed.

3. If in addition to red and green the ordinary railway lanterns with white light were also used, the probability that a man with abnormal color-sense would make mistakes, would be materially increased in both cases 1 and 2.

4. If the signal lanterns, white, red and green, were shown at a distance of 500 to 600 metres (550 to 650 yds.), the number of mistakes made by the color-blind and by those having an abnormal color-sense would already amount to several per cent.

5. If the different signal lanterns, white, red and green, were not always shown at the same distance and having the same brightness, but having different brightnesses, and at different distances, then, in the case of the majority of the color-blind, the number of correct and incorrect answers would approximate to that which probability would indicate as the result of mere guess work. In the case of those with an abnormal color-sense, the number of errors would be less, but would still be considerable.

6. If the signals in case 5 were only shown a comparatively short time, a few seconds only, before a decision as to the color shown must be arrived at, then in the case of the color-blind, the percentage of correct answers would be very nearly the same as that obtained by mere guess work, without looking at the signals. As there are three colors, the probability of a correct answer is one-third. The same would be the probability in the case of one perfectly blind. A person with an abnormal color-sense would only obtain very slightly better results.

7. Let us assume that instead of showing one single light, several are shown simultaneously next to each other; then, assuming the other conditions of cases 1 to 6 to remain as before, in the case of a color-blind person, the probability of an erroneous answer is scarcely increased, in fact is possibly slightly reduced. In the case of a man with an abnormal color-sense however, the juxtaposition of several lights introduces a fresh source of error, the abnormal contrasting of colors. The probability of an erroneous answer is much increased in the case of a man with an abnormal color-sense, if several colored lights are placed next to each other.

It would require too much time and space to give the experimental proofs of all these seven propositions. The only point of interest is the general proof that there are conditions under which the color-blind and those with an abnormal color-sense readily mistake colored signals, while those with normal sight do not mistake them; and these are conditions which often turn up in railway and marine practice:

A color-blind man, who can distinguished between red, green and white lanterns, without making a mistake, if they are all of equal brightness and seen at one same moderate distance (say 100 metres), makes mistakes if the lanterns are further off, if they are at unequal distances, if they are of unequal brightness, if the glasses are not equally clean, and if he has only

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a comparatively short time available in order to make up his mind.

An interesting light is thrown on the lantern examination system by the investigations of Dr. Stadfeld, of Copenhagen. He subjected a large number of sailors, whose color-sense had been tested by means of signal lanterns and found normal, to examination, firstly by repeating the signal-lantern tests and then by other methods. The results obtained are recorded in Dr. A. Krogh's paper: "Nyere Undersögelser over Farveblindhed og abnorm Farvesans og deres praktiske Betydning," published in Danish Söfartsidende, Vol. XIII, Nos. 43 and 44. Dr. Stadfeldt found that of 295 mates examined, 17 had a defective color-sense; in 11 of these cases, the abnormality was recognizable when the lantern test was used. This shows that it is possible to detect an abnormal color-sense, in some cases, by means of the lantern test; but careful examination by a specialist is required, and much more time than the medical men who have to make these tests officially are able to afford.

A man with an abnormal color-sense also makes mistakes in such cases, although not quite so frequently, especially as far as red is concerned, as one who is wholly color-blind.

The driver who is on an express locomotive traveling at high speed, frequently has to perform important actions a few seconds after seeing a colored signal. He will quickly pass, on his locomotive, signal lanterns the glasses of which have just been cleaned and which are burning brightly; perhaps immediately afterwards, he will see lanterns on the glasses of which soot is deposited, or the lights of which are not burning brightly; or are dimmed by fog; he must recognize the signals with certainty for a considerable distance, sometimes from one-half a kilometer (550 yards), as he can hardly stop his train within a shorter distance, if he has the ordinary brakes available.

These conditions are very different from those which prevail when he is examined "on the stop," that is to say, when he is shown several times in succession a red light and several times a green light, generally both at the same distance, the brightness remaining constant, and when he is allowed as much time as he likes for making his observation.

Similarly, the conditions under which a sailor has to recognize colored lights at night are much less favorable than during this simple examination with lanterns. He must recognize signals at a distance very quickly, and it may be disastrous for him should he confound a dimly-burning lantern with white light with a red or a green lantern, or still worse if he is unable to distinguish the two side-lights of a ship from each other with certainty. The side-lights of a steamship should, in clear weather, be visible, to a normal eye, at a distance of 1 nautical mile, and their colors recognizable.

A rather remarkable proposal was recently made, if I remember correctly in an English publication, based on similiar considerations to those mentioned above, and that is, that the color-sense of employes should be tested while running on an experimental section, specially constructed for the purpose. The section was, as far as I remember, to be either a mile or a kilometer (0.62 mile) long.

Such a proposal is hardly worth consideration. In fact it hardly seems possible to me, in practice, to carry out examinations by means of actual railway signals (even leaving examinations on a moving train out of consideration); for if the examination is really to be successful in detecting color-blindness and still further, abnormality of color-sense, a very complicated installation would be required. It would be necessary to have several sets of red, green and white lanterns at varying distances, and it would have to be possible to light up and extinguish any combinations desired, and keep them alight any length of time required; and this control would have to be from a distance, from the place where the examiner and examinee were placed. If the changes of light were effected directly by electric mechanism, without being in any way impeded by either telegraph or telephone traffic, an experienced examiner would probably be able to form, in 1 to 15 minutes, a reliable judgment of the color-sense of the examinee. But how many complaints are already made by examiners if they have to spend two minutes on the examination of each individual!

That such a proper system of "on the spot" examination cannot be generally introduced is clear. The very large expense involved would of itself make it impossible. It is certainly true that systematic examinations with railway lanterns, made with all proper precautions, utilizing all modern knowledge, of persons having perfect and defective color-senses of the different kinds, would be of considerable interest. As far as I know, such have as yet not been made, and the experiments, which I describe below, will therefore perhaps be of interest to those concerned in such matters.

All the experiments described have the one common feature, that the person examined was only shown such lights as are used in the actual railway service, namely, red, green and so-called "white," i. e., artificially produced light without a colored glass screen. As sources of light, incandescent carbon filament lamps were used, which give a light which is qualitatively very much the same as that given by petroleum lamps. The colored screens used were made of pieces of the standard colored glass used on the Prussian State Railway, namely, ruby glass and the well-known blue-green.

In the first series of experiments, which will be described here, care was taken that the persons examined could always see the lights well-defined and sharp (short-sighted persons used proper glasses, persons with amblyopia were excluded altogether), and that they could look at the lights as long as they liked before stating what color they saw. The signal lights were always shown bright on a black ground, as they would be at night on a railway.

TESTING ARRANGEMENTS.

The tests were arranged so as to make it possible to show the three railway signal lights white, red and green in varying brightness and magnitude of field, without affecting the quality of the light by the alterations in the brightness or in the magnitude of field. As it was out of the question to obtain the changes in the magnitude of the field by setting up a number of railway signals at distances varying from 100 to 1,000 meters (from 110 to 1,100 yards), it became necessary to imitate these conditions as closely as possible. This was done as follows:

1. Three holes were bored in the door between two rooms of the physiological institute; they were 12 centimeters (4¾ ins.) apart and had a diameter of 1 centimeter (⅝ in.). In front of each of these holes, a revolving metal plate was placed; three pieces of glass, red, green and neutral-tinted, were let into this plate, the object of the neutral-tinted glass being to reduce the brightness of the white light to approxi-

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mately the same as that of the colored lights, but without in any way affecting its tint. Thus each of the three holes could be made to show each of the three colored lights, if they were illuminated from behind by the source of light used.

2. In front of the plate with the colored glasses, another revolving metal plate was placed, in which there were six round holes having diameters of 1, 2, 3, 4, 5 and 6 millimeters (3-64, 5-64, 1-8, 5-32, 13-64 and 15-64 in.) respectively, so that the fields of the colored lights shown could be given these different magnitudes. Moreover, it was possible to cover up each individual field entirely.

3. Behind the colored glasses, and consequently between them and the source of light, one or two pieces of ground glass could be interposed. The introduction of one such glass reduced the brightness of the light to about one-half or one-third, of two to about one-sixth of its original value.

The examinee was seated in the room at a distance of 5 meters (17 ft.) from the lights; this room was kept so dark that he was unable to ascertain, by means of any secondary indications, what size of field and brightness of light he was being shown.

Under these conditions, when the largest stop of 6 millimeters (15-64 in.) was used, the angle of vision of the examinee amounted to 4 min. 6 sec. The angles of vision of the six stops are as follows:

Diameter of stop, 6 millimeters (15-64 in.), angle of vision 4 min. 6 sec.

Diameter of stop, 5 millimeters (13-64 in.), angle of vision 3 min. 25 sec.

Diameter of stop, 4 millimeters (5-32 in.), angle of vision 2 min. 44 sec.

Diameter of stop, 3 millimeters (⅛ in.), angle of vision 2 min. 3 sec.

Diameter of stop, 2 millimeters (5-64 in.), angle of vision 1 min. 22 sec.

Diameter of stop, 1 millimeter (3-64 in.), angle of vision 41 sec.

By way of comparison, let us consider what (approximate) angles of vision are given by the signal lanterns used on railways and ships. It is not possible to give absolutely accurate statements, as we are never dealing with uniformly illuminated disks of definite standard size.

In the case of an ordinary railway signal lantern, a petroleum lamp burns behind a clear colored or white plate of glass, which is circular and has an available diameter of about 15 centimeters (6 ins.).

It is evidently not correct to consider the flame alone as representing the surface which is emitting light, as close to it, both to the right and to the left, there are metal reflectors. But even if these are in the best possible condition and polished like mirrors, they cannot give the whole surface of the glass an even approximately uniform brightness. However the objects aimed at, namely, to utilize by the reflection more of the illuminating power of the lamps and to obtain a larger bright field than the flame alone would give, are no doubt attained. If in calculating the angle of vision, I assume the diameter of the field to be 15 centimeters (6 ins.), then any error that I make is certainly in favor of the railway lantern. Actually, the angles of vision must be somewhat smaller.

Under these assumptions, the railway signal lantern would give the same angle of vision as the largest stop (6 millimeters [15-64 in.]), if the observer was 125 meters (137 yds.) from the signal. The smallest stop (1 millimeter [3-64 in.]) would correspond to a signal lantern at a distance of 750 meters (820 yds.). A difference between my experiments and the conditions prevailing in the railway service arises in so far as in the former case the magnitude of the field is varied by the use of stops, whereas, in the latter, it is varied under normal conditions (i. e., if the glass does not become dimmed or the reflectors lose their brightness) merely by change of distance; consequently, no allowance is made for any reduction in the transparency of the air. This could well be left out of consideration, as when my apparatus is used the examinee is again (just as in assuming the diameter of the bright surface of the railway lantern) under more favorable conditions than an employe at work on the railway. Any mistakes the examinee might make when tested by my apparatus, would be made with still greater certainty under the less favorable conditions of actual practice.

Later on, I will consider the influence exercised on the visibility of the signals by any thickness of the air, produced by fog, smoke, rain, etc., preventing clear definition and giving diffusion circles; I will then also consider the influence of the time factor.

A few words may also be said about the signal lights used on ships. A very definite visibility and design is prescribed for them.* The colored sidelights, which alone are of interest to us, must be visible at a distance of 2 nautical miles. The circular petroleum burners or electric incandescent lights are in addition surrounded by a polygonal system of lenses and have reflectors. As in the case of the railway lanterns, it cannot be expected that the whole surface will be uniformly bright; but a considerable part of it is.

The diameter is to be between 14 and 18 centimeters (between 5½ and 7 ins.). A diameter of 18 centimeters (7 ins.) would at a distance of 2 nautical miles give an angle of vision of 10 sec.; one of 14 centimeters (5½ ins.) an angle of vision of 8 sec.

The smallest stop I used when showing lights to my examinees thus corresponds to the lanterns of a ship shown at a distance of 750 meters (820 yds.), that is to say, less than one-fourth of the distance at which such lanterns have still to be recognized.

If I here mention all these figures, it is only to show that my examinees observed the signal lights under more favorable conditions than those obtaining in practice, and that consequently any mistakes made during my examinations would still more certainly be made under the conditions existing in actual practice. In all cases where figures had to be estimated, I always took the limit which would give the most favorable chance to my examinees.

I must also remark that in all the experiments the examinee was first informed that the lights he would be shown would only be the three railway signal lights, white, red and green, and that the so-called "white" was in reality the somewhat yellowish-red light of electric incandescent lamps. The examinees were only subsequently informed whether their answers were right or wrong.

It would be useless to give the records obtained with persons of normal sight, as under the given experimental conditions, with the colors and illuminating powers used, no mistakes are made, not even if the brightness is reduced to one-tenth its original value.

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*Compare: Untersuchungen uber Sichtweite und Helligkeit der Schiffspositionslanternen u. s. w., ausgeführt von der Direktion der Seewarte, Hamburg, 1894.

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If the signal lights are shown to an entirely unprejudiced person with normal sight without giving him any previous explanation, and he is then asked what colors he sees, he at once correctly recognizes red under all conditions. In the case of green, some individuals doubted at first whether it was green or blue, but in no case was it confounded with white or red. The "white," if it was burning bright and the field not too small, was at once called by all, without hesitation, white or yellowish white. But when the brightness or the magnitude of the field was reduced, it was asserted more definitely that the white was not a pure white, but rather a yellowish or reddish white. But no person with normal sight was tempted to confound this light with red and to call it a red light.

This is an interesting point theoretically and also of importance if we consider the probability that a color-blind employe of a railway will make a mistake. But of much greater importance is the fact that in spite of all practice, a person who had very sharp eyes and had an unlimited length of time available for observation, still made mistakes to the extent of 16 per cent. I do not doubt that a color-blind locomotive driver could arrive at a similar figure; moreover, if very many series of such trials were made, a series with a lower percentage of error would be bound to turn up occasionally. But if only one-tenth, or even only one-hundredth, of such mistakes were to occur, this would already be a definite proof that it was possible to allow color-blind persons to remain in a service, in which a number of lives depended on their ability to distinguish colors properly.

I have made similar series of trials also with several other color-blind persons; some were red-blind, others green-blind, but all were persons with acute or very acute vision and quickness of mind. As in the case of persons with an abnormal color-sense (to be considered later on), I always told them before the first trial was made that only the three colors, red, green and "white," were in question, and I immediately added that the latter was only a nominal white, as it was the light given by an ordinary electric incandescent lamp.

All the color-blind persons tested told me at once after the first few trials, that they found the problem impossible, as all the lights appeared similar, and in fact appeared to them to be yellowish. They then, with laughter, at my request tried to guess the colors as nearly as they could; but it was evident that they had no notion what the colors really were.

RESULTS OBTAINED WITH PERSONS HAVING AN ABNORMAL COLOR-SENSE.

There would have been no particular advantage in making special series of trials of persons with dichromic vision, had I not had the intention to examine, by the same method, persons with abnormal trichromic sight; as at present not yet everybody is sufficiently clear about the incapacity of the latter.

I had expected that but few mistakes would be made by persons with an abnormal color-sense when shown separate single lights, unless indeed the lights were very dim and only a short time was allowed for observation, conditions which were especially avoided in this series of trials. The number of mistakes consequently surprised me.

Still more important is the following behavior which is very typical of persons with an abnormal color-sense. If several lights are shown together, the answers given by a person with an abnormal color-sense soon begin to be uncertain. Thus he will for instance describe a red light in the first moment as red, and then will at once correct himself and say that after all it is green; and so he will change his opinion several times, probably, in connection with intentional or unintentional changes in the attention with which he regards the light. Neither in the case of persons with normal sight nor in that of those who are color-blind are similar observations made.

If two or three lights are shown simultaneously, then the phenomena of abnormal simultaneous contrasts become very clearly apparent in this method of examination. In the presence of one or two bright red lights, the person with an abnormal color-sense will think that a white, or even a small or less bright red light, is green. Not quite so frequently will the name "red" be given to a white or a feeble green light, placed near a bright green light.

If we extract from the reports of persons with an abnormal color-sense only those trials, 30 in number, in each of which 3 lights were shown side by side, we find that of the 90 lights named 37 were incorrect. It is true that I selected the combinations of color with a view to the appearance of contrasts, so as to increase the chances of error.

In the case of series 14, there are also many errors when each light was shown alone, far more errors than would usually occur in the cases of persons with an abnormal green-sense. It was an extreme case, closely approximating to green-blindness, but still trichromic. In the case of other people with an abnormal green-sense often but few mistakes occur when 20 to 30 solitary lights are shown in succession, at least as long as the brightness is not reduced.

The most frequent mistake made is the confounding of green and white. As soon, however, as several lights are shown at once, then even those who are best among the persons with an abnormal color-sense, at once make their typical mistakes.

A remark made by a person with abnormal red-sense was of interest to me. After completing a series of trials with him I once more showed him the lights, naming them; and he informed me that what he by contrast with the red supposed to be "green," seemed to him to be a much stronger and purer green than the light officially called green. The latter seemed to him very whitish.

While I reserve for myself the general discussion of the results here submitted, and of their significance as regards the efficiency of persons with color-blindness or with a defective color-sense for the railway and marine service, until I have given particulars of experiments made under other conditions, I would only once more emphasize that the experimental conditions under which the above trials were made, were such that the efficiency of the persons concerned (with color-blindness or a defective color-sense) was placed in far too favorable a light, although the number of mistakes made is certainly already surprisingly great.

The trials also show that it is very possible to demonstrate very evidently the defective color-sense of such persons by means of several railway signal lights, if we only take into consideration that the confounding of red and green is not the only item coming into consideration, but that it is important to distinguish red, green and "white," and further that the lights are seen in practice at different angles of vision and having varying brightness and clearness; all these circumstances have to be taken into consideration when tests are made. Finally the reciprocal influence resulting when several lights are visible simultaneously, must not be left out of consideration.

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