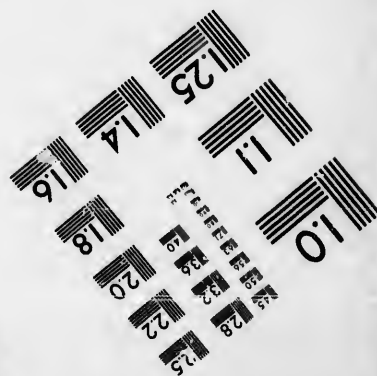
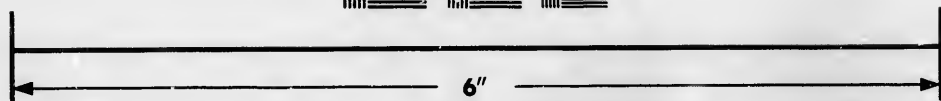
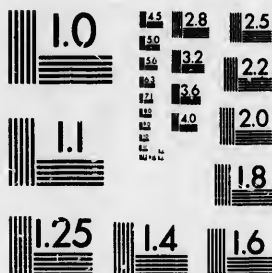


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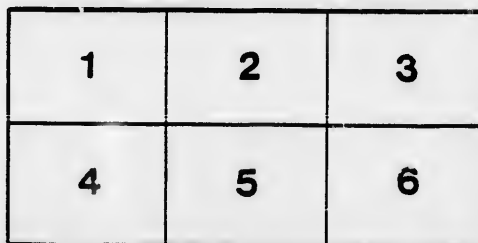
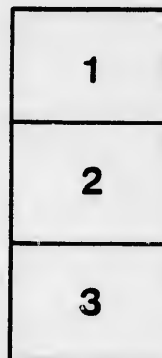
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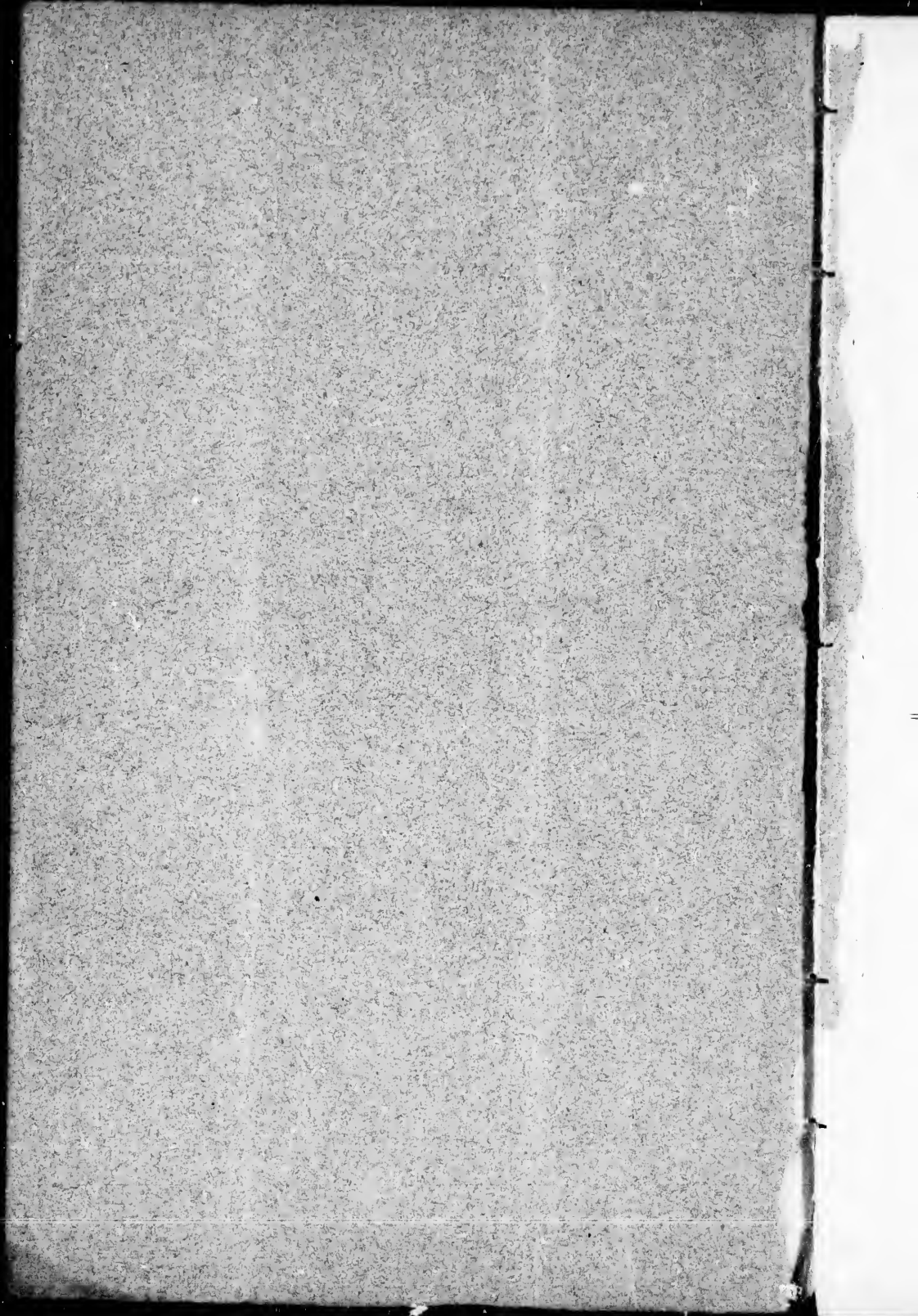
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COLOR-BLINDNESS.

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COLOR-BLINDNESS.

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RESOLUTION ADOPTED BY THE BOARD OF SUPERVISING INSPECTORS OF STEAM-  
VESSELS, JANUARY 25, 1881.

*Resolved*, That the thanks of this board are due, and are hereby tendered, to Professor B. JOY JEFFRIES, of Boston, Mass., and Professor W. H. CARMALT, of Yale College, New Haven, Conn., for their thorough and exhaustive discussion of the important question of "color-blindness," and valuable information imparted to this board in regard to the various methods employed in determining color-blindness in persons; and that the Supervising Inspector-General inform the gentlemen, by letter, of the action of this board.



## COLOR-BLINDNESS.

REMARKS BY DR. B. JOY JEFFRIES, OF BOSTON, MASS., AT THE TWENTY-NINTH ANNUAL MEETING OF THE BOARD OF SUPERVISING INSPECTORS OF STEAM-VESSELS.

The special study of the physiology of vision has been intimately associated with my professional work as an ophthalmic surgeon. Color-blindness from disease is one of the symptoms we have to deal with. A knowledge of it as a *congenital* defect, not associated with any discoverable lesion of the eye or the brain, has for many years impressed me with its probable danger on land and sea. Scientists or physicians have had, however, no means of detecting it so quickly and so readily as to enable them to thereby engage the attention of those in authority who had the power to establish rules and regulations of control for the protection of the community from this heretofore hidden danger. Therefore, as soon as my friend Dr. Frithiof Holmgren, professor of physiology at the University of Upsala, Sweden, published his monograph on color-blindness and its dangers and detection, I saw that his method of examination with the worsteds was so sure and so rapid in the hands of an expert, that I had no longer any hesitancy in publicly calling attention, in the early part of 1877, to the danger from color-blindness on our railroads and on the sea, from the necessary use of colored signals, &c. I commenced investigations by his method, and my first results are in the Ninth Annual Report of the Board of Health of Massachusetts. I was soon urged to write a manual upon the subject, incorporating Professor Holmgren's monograph, which had in part been published by the Smithsonian Institution. I accordingly wrote a book on "Color-blindness, its dangers and its detection," giving a history and explanation of this curious defect, the results of my own personal examination of many thousand males and females, those of other examiners in Europe with whom I had corresponded, the various methods of detecting the defect, and the *amount* of it in any given case; the explanation of how it had and does escape notice or detection, the rules and regulations of European countries for its control on land and sea, and a bibliography of some seven hundred articles written on the color-sense. The book quickly attracted the attention of the medical departments of the Government, and it was adopted as a manual to be, with the Holmgren worsted test therein recommended, distributed to the medical officers of the Army, Navy, and Marine-Hospital Service, to guide them in the examinations they were called upon to make under orders of their several Departments.

This book was only the second one in English on this subject; a monograph from Professor Wilson, of Edinburgh, in 1852, being the other, which had failed to draw public attention to the subject as it deserved, the reason undoubtedly being the lack of such a quick and practical test as that of Professor Holmgren, since brought forward. This personal explanation has been necessary to show that the subject was an entirely new one to the laity, the profession, and even to the

specialists who had not become practically acquainted with it. Therefore I have been and am called upon for advice and explanation by medical officers and others whose official duties interest them, directly or otherwise, in the detection of color-blindness. Such advice and explanations I have always given freely to the best of my ability, and have allowed no sacrifice of time or money to prevent me from responding to each and every call to talk, to lecture, to explain, to answer inquiry by letter, or to appear before interested authorities, as the legislative railroad committees of Massachusetts and Connecticut, and the Naval Committee of Congress, and finally before many scientific societies. Especially have I felt it my duty to assist those in authority in understanding the subject before making rules and regulations governing visual defects and color-blindness. Thus it is that I come before this board at my own expense, stimulated only with a desire that, so far as I can make clear, they may be able to protect the community from the hidden danger of defective sight, by discriminating rules based upon the practical facts of scientific observation.

The Supervising Inspector-General says, in his annual report, that the rules in reference to color-blindness "were the most important, probably, ever adopted by the board." Now, the necessity of physical examination of soldiers was finally recognized by the community during the war. The crystallization, so to speak, of society in this country which has since so rapidly followed, has of necessity led to the required physical examination of various classes in civil life, and has naturally often met with great opposition on the part of those subjected to it. Sympathy is always with the defective person, as amongst us the rights of the community are nearly universally sacrificed to those of the individual. This is, of course, a potent cause of the difficulty of protecting the community by laws which render physical examinations necessary.

The railroad committee of the legislature of Massachusetts told me, when I was arguing before them, that I never should succeed in making them "oculists." But since they, as any body of the laity, would not accept or act upon the opinion and testimony of professional experts *unchallenged*, I had to consume valuable time in explaining to them some of the laws of form and color-perception, without a recognition of which it is impossible to understand even the general bearings of this subject of defective vision from poor eyesight or color-blindness. Your board, therefore, must permit me to draw their attention to some of the conditions of our sense of sight and color, which bear so directly on what now concerns us.

Through the eye we receive two impressions, namely, *form* and *color*. These are very distinct, and not at all necessarily connected. The complex arrangement of the internal part of the human eye, by which it resembles perfectly a *camera obscura*, is necessary in order that a sharply-defined picture of external objects should be received on our retina. The slightest congenital or pathological change from a normal condition causes imperfect vision. Now, this is not the case with reference to color. The curves of the refracting media of the eye may be very untrue, the media themselves not transparent, and yet the impression of color may be quite perfect. A person so blind with cataract as to be only able to tell where the window is, may be able, if not color-blind, to distinguish quite delicate or pale shades of color. Through a ground-glass window we can readily see the color of a signal-light, though we

cannot, of course, distinguish the form of any object. Hence the great value, practically, of *color* for signals over *form*. As is well known, all attempts at the introduction of *form* for *color* in signals, on the sea as well as on railroads, have been given up as useless.

There is a natural condition of our sense of form and color which must be understood, as it may bear directly upon the explanation of mistakes in quickly discerning form or color signals. It is only at the centre of our retina that we have perfect form perception. From here outwards our power of seeing objects distinctly diminishes rapidly. This fact we are almost unconscious of, since we can so easily turn our eyes towards an object and let the image of it fall upon this spot of best sight in the centre of the retina. Close one eye and look at a word as long as "constitution," in such print as this, and you will notice that really only the first three or four letters are distinct, and we must, as is said, run our eye along to catch the rest of the word. Hence, when gazing steadily at an object ahead of us, one much to one side will escape notice.

Now this same law holds true as to color. It is only at the centre of the retina that we have our best color sense. Our feeling for the color fades from here outwards. Close one eye and look with the other at a red wafer on your thumb-nail. Then, keeping the eye fixed, move the hand slowly off to one side, and it will be found that the wafer, if red for instance, loses its color, and may appear even black. This fading from the centre of the retina outwards varies with the different colors.

Another natural or normal condition of our form-sense and our color sense is very important to be recognized and remembered. It is the persistency of the impression on the retina. If we gaze steadily for a time, say at a picture in a dark frame on the wall, especially when we open our eyes in the morning after rest and the retina is more sensitive, then when we close our eyes we still see the picture. Now if we open them and look at another portion of the wall or at the ceiling, the picture will seem to have gone there, and the frame, instead of being dark, will appear light; moreover, if the wall or ceiling we look at is further off than that on which the picture hangs, then the frame will appear larger. If the wall or ceiling is nearer, then the picture will appear smaller. A pilot steadily gazing at the outline of a schooner in a dim light will see another in the direction he turns his eyes.

This is true, also, of color, and hence of importance, as is readily seen. Gaze steadily at this bright-red disk, about six inches in diameter, as I hold it up against the wall, whilst I count twenty. Now, when I remove it and you continue to look at the wall where it was, the retinal impression will continue and you will still see it, but suddenly, instead of *red*, you see a *green* circle; the complementary after-image, as it is called. Just the same as you see with this green disk—a complementary or rose-colored spot appears in its stead. If you gaze at the setting sun when it is a ball of red and then turn to the east you will see a rising *green* one. A man who has gazed steadily at a red *port* light will, on turning away, see suddenly a green *starboard* light. I mention these curious phenomena of *normal* vision as they must not be forgotten in investigating mistakes or accidents, and have a direct bearing in all attempted tests of the color sense with lanterns.

Scientists at present generally admit but three base or primary colors, namely: *red*, *green*, and *violet*. Now, with the central portion of our retina we can perceive all three of those colors. In a zone outside of

this, red fails us; and again, in a zone outside of this, both red and green fail us, and we can perceive only blue or violet. Color-blindness is the failure of one or more of these three sensations, viz: red, green, and violet. There is red-blindness, green-blindness, and violet-blindness. The first two practically involve each other. Violet includes blindness to yellow. It is very rare indeed. When, therefore, we use the term color-blind, it means red or green-blindness; one involving the other, so much so that the two are sometimes considered the same, and called red-green blindness. This must be remembered, since a person reported red-blind is supposed to be able to see green as the normal-eyed, which is not the case. A color-blind does not see red as green or green as red, but both appear *grayish* to him. In proportion as he is color-blind, all colors containing red and green appear us if so much gray or white and black mixed had been used instead of the pigments. Hence a white lantern when smoky will give him the sensation of a green or a red one. He has learned instinctively to judge of the color of light by its intensity. Very naturally, therefore, if he calls them by the color name we do, he is supposed to see them as we do. This I will return to hereafter.

The danger from color-blindness is, of course, in proportion to the amount. Now, examinations of males and females of all races, colors, countries, ages, and degrees of civilization or education, have proved that about four per cent. of the former and one-fourth of one per cent. of the latter are more or less color-blind. The result of my own testing 18,556 males was finding 764 more or less color-blind, or about 4 per cent.; and of 14,557 females, only 11 defective. I would say at once that this must be regarded only as a sexual difference, and has nothing to do with women's greater familiarity with colored objects. One great reason why this has not been known till now is, that we have not had the means of testing large numbers of people rapidly and with accuracy. But you will at once ask, how is it that the color-blind have escaped detection, and do so now in every-day life? I should take up too much of your time to explain this in detail, and would refer you to chapter eleven, of my Manual. It is of itself one of the most interesting points of this curious defect. How even a portrait or landscape painter may escape detection, except by accident, is well worth seriously considering in relation to the necessity of experts in testing pilots or railroad employes.

Color-blindness is congenital, and it does not change as one grows up, nor can it be altered by any practice with colors. It may be total, that is, a person may have no sensation whatever of color, and the whole would be to them but shades of gray. It is only partially palliated, but not altered in artificial light. The color-blind do not make such gross mistakes by gas-light or when looking through a pale lemon-colored glass like gas-light. It is a mistake to suppose that therefore they may see colored signals better by night. This is *transmitted* light, taking only the color of the glass, but little modified by the source of illumination. It is only reflected light from colored objects which is changed so as to assist them. It was supposed that their vision was *changed* or altered by looking through a solution of fuchine, as in this wedge-shaped little tank. This is a mistake. The relations of light and shade are changed, and these being what the color-blind decide by *in naming colors*, they, and others, concluded the color sense was really altered. This is referred to because it has passed from journal to newspaper that color-blindness was thus curable.

Color-blindness is very hereditary; of importance, where a son follows the parents' or grandparents' profession. It follows, as cases in families show, the general law of heredity; hence the high ratio in a community containing many color-blind families. A practical point here is, that after accident from collision or otherwise, and those implicated are killed or drowned, we may, perhaps, judge whether it was due to color-blindness by finding whether they belonged to color-blind families, and had blood relatives who are defective.

Color-blindness may exist congenitally in one eye. Persons who can be put into the so-called hypnotic condition may be temporarily rendered color-blind thereby. Moreover, the color-blind who can be thrown into this condition may be made to see colors whilst hypnotized.

Color-blindness, besides being congenital and hereditary, may be acquired. It is a symptom of some diseases of the brain and the optic nerve. Men, after any exhausting disease like typhoid fever, should be tested before again assuming their duties. The necessity of periodic examinations, for instance with pilots as often as they are relicensed, is thus readily understood. This, quite aside from the necessity of testing their visual power, which may have decreased from many causes during the preceding year.

Professor Nuel, of Louvain, Belgium, sent me the following account of a case under his care, which was reported to the Royal Medical Academy:

"Joseph Dhur, of Turinne le Grosse, et 20, laborer on the Grand Central Road, consulted me January 12, 1878. I found that he had been in the Hospital St. Pierre, at Louvain, a year before, with trouble in the back of the right eye, (*une neurite retrobulbaire.*) From this he recovered to having vision two-thirds of the normal. After a month at the hospital, he returned to his work and continued at it a year without his condition being noticed. During this year, however, Dhur had to act one day as a guard. In the evening he put out a *green* instead of a *red* lantern, and returned into the guard-house. Having for some reason to go out a few minutes later, he passed near the lantern, when suddenly he was in doubt as to the color of the signal. Looking at it more closely with his left eye, (which was then healthy,) and comparing the two different faces of the signal, he found that he had in reality shown the *green* instead of the *red* light. These facts he even now recalls very well, and distinctly remembers how he could not distinguish between the red, green, and white lights with the right eye, and could only tell them by looking close-to with his left. The circumstance so affected him that he consulted a physician, who dismissed him with the remark that he had probably been drinking.

"On examination, I found the visual acuteness of the left eye normal, of the right six-ninths of normal. Visual field of left eye for white, normal; of right eye only 30 degrees up, down, and inwards; outwards, 40 degrees. The color sense is greatly altered in the right eye. Red and green are confounded with gray; violet appear blue; the patient could only distinctly distinguish yellow and blue. In the left eye the color sense for red and green was diminished; the object had to be larger than what the normal eye could recognize.

"Here, then, we have an employé with defective color sense, from a disease of the nervous centres, continuing his occupation for a year; but the first time he had to give the signal, displaying *green* for *red*. The danger can be readily appreciated. Had he been an engineer an acci-

dent would certainly have resulted. I would especially recall the fact that his right eye, so defective in color sense, had a visual power of six-ninths of the normal, which would have allowed him to have continued in service. And still further, that the color sense had also fallen in the left eye, where there was still normal visual power. The patient's doubts and my preliminary examination were convincing. Later the left eye also confounded red and green, yet its visual acuteness remained normal or nearly so.

"Clinical observations have sufficiently demonstrated the not infrequent occurrence of acquired color-blindness. If, now, its frequency has already attracted attention, it should be still further remembered as being so much more dangerous than when congenital. In acquired color-blindness the person may for many days be quite unaware of his altered color-sense, and would only recognize it after repeated mistakes, any one of which under favorable circumstances may prove fatal.

"Whenever the surgeon suspects acquired color-blindness, the first thing requisite is the examination of the visual field for colors. In these cases we can also question as to color names, since the individual has known them, as we may prove by the color sense of his other eye if perfect, or his having still some color sense remaining. Most certainly the first requisite in the control of color-blindness in certain public services, as of the anomalies of refraction in the army, is to insist on the examiner having a good knowledge of ophthalmology."

*Injuries* about the head, such as sailors and railroad employés are particularly subject to, may cause diminished color perception. Observed cases might be cited in support of this statement.

Alcohol and tobacco, each alone or when combined, produce, in poisonous doses, a deterioration of the vision and color sense, as has been long known by specialists. This question has been very carefully studied and reported on by ophthalmic surgeons in Europe, England, and this country, quite recently. The results are the same, namely, that alcohol and tobacco together, or each alone, do cause failure of eyesight, both as to form and color. And, what is most important to be remembered, the color-blindness may exist when the person sees otherwise quite well. Hence such a person would escape detection. One of the writers on this topic, Professor Nuel, above quoted, very truly remarks: "The ordinary methods of examination would not detect such a color defect, especially at its outset; perimetric examinations are indispensable."

These additional and peculiar tests, requisite after sickness and injuries, are therefore also necessary where there is any suspicion of alcohol or tobacco, particularly as it is the central portion of the field which is affected, just where we have our best vision. Now the point is, that such tests can only be applied by skilled surgeons. The danger from partial or total color-blindness from these causes is the greater since they are sure to be overlooked by non-experts, especially as the visual power for form may be so good as not to call the person's attention to his own trouble, and cause him even to escape detection when examined by the laity. Hence, therefore, the absolute necessity for periodic examinations of those known to use alcohol or tobacco very freely. And similar periodic examinations by skilled experts are equally requisite for all injured or contused, and those convalescent from exhausting diseases, before they return to their positions.

It will now at once be asked of me, if one out of every twenty-five

of our male friends is likely to be color-blind, how is it that this defect has escaped detection? A railway official said to me, "I have been connected with railroading forty years, and never heard of color-blindness; if it exists I must have known about it." So, also, the head-centre of the Brotherhood of Locomotive Engineers never had heard of color-blindness. For a full answer and explanation I must refer to the special chapter in my Manual on "Concealment of color-blindness in practical life." I there show how the color-blind deceive themselves and others, and, growing up in ignorance of their defect, escape detection. To this must be added the very important fact that, till very recently, methods of testing for color-blindness have been used which were wholly inadequate to expose particularly the lighter forms of the trouble. I may also be permitted to quote the following from that chapter:

"The color-blind who are quick-witted enough to discover early that something is wrong with their vision by the smiles of their listeners when they mention this or that object by color, are equally quick-witted in avoiding so doing. They have found that there are names of certain attributes they cannot comprehend, and hence must let alone. They learn, also, what we forget, that so many objects of every-day life always have the same color, as red tiles or bricks, and the color names of these they use with freedom, whilst they often, even unconsciously, are cautious not to name the color of a new object till they have heard it applied, after which it is a mere matter of memory, stimulated by a consciousness of defect. I have often recalled to the color-blind their own acts and words, and surprised them by an exposure of the mental jugglery they employed to escape detection, of which they were almost unaware, so much had it become a matter of habit. Another important point is, that as violet-blindness is very rare, the vast majority of defective are red or green-blind. These persons see violet and yellow as the normal-eyed, and they naturally apply these color names correctly. When, therefore, they fail in red or green, a casual observer attributes it to simple carelessness; hence a very ready avoidance of detection. It does not seem possible that any one who sees so much correctly, and whose ideas of color so correspond with our own, cannot be equally correct throughout, if they will but take the pains to notice and learn. Color-blindness is also a source of petty mortification, which teaches its possessor to be on constant guard over himself in avoiding exposure and its accompanying irritation. The intelligent color-blind finds many ways of drawing a decision of color from those he is in contact with, and always lets shop-keepers pick out the colors he calls for, just as the color-blind shop-keeper lets his customer do the same, if he can; and when he fails in this, and makes mistakes enough to lose his place, he can take refuge in the mourning stores, where his defect is an advantage."

Prof. Holmgren well says: "To judge correctly of color-blindness and the various practical questions connected with it, it is of the highest importance to distinctly observe the difference between the manner in which the color-blind person *sees*, and the manner in which he *names* colors. The sensation is based upon the nature of the sense of color in the organization of the optic nerve from birth. The *name*, on the contrary, is learned. It is conventional; it depends upon exercise and habit. The names of colors are naturally the objective expression of subjective sensations; but, on the other hand, they are regulated by

the system of the normal sight, and cannot, consequently, agree with that of the color-blind. They can, nevertheless, be learned by the latter, and even applied correctly in many cases. There is connected with this fact a peculiarity of utmost importance, practically, to the question in point, and one which has given rise to the most serious embarrassments and misunderstandings. This has been, and is still, one of the chief causes of our erroneous ideas on the subject of color-blindness existing in the masses, because it is the veil under which this defect usually conceals itself from our observation in every-day life, and under which, even to the last moment, it will succeed in escaping discovery in cases where, as frequently happens, the methods of exploration employed are indecisive or are based upon erroneous principles.

"If we reflect on the condition of the color-blind, it is difficult to understand how he can avoid being detected in his daily intercourse with those endowed with normal sight, and yet experience has sufficiently controverted this idea. That which we have acquired in examining *en masse* the *personnel* of a railway, for example, where it is required night and day to give attention to colored signals, is singularly worthy of notice. We learn by it that a number of color-blind were discovered, although their defective sense of color had never been suspected by themselves or any one else, and the majority had correctly performed their duties."

I have said that "no one can have tested and talked with many color-blind without being convinced that we can hardly set any limit to their capacity for learning other attributes of colored objects, and recognizing and remembering their color names through these alone. Thus, as we now well know, they may even deceive themselves, as well as others, into the belief that they have gained by *practice* a color perception they were not born with."

The color-blind have even succeeded as landscape and portrait painters, as they have seemingly succeeded as pilots and railroad engineers. If the painter's colors are not marked or chosen for him detection may result, as shown by the following case: "A student of the Royal Academy of London, who was selected, not only by the authorities, but also by his fellow-students, as having about the best perception for form and power of light and shade, turned to the use of colors. In this it was naturally supposed he would exhibit extraordinary talent, and become a great painter. He was allowed to take a portrait by Titian from the National Gallery and have it in a small room to himself. There he copied it to his best ability, as he stated to the principal and to his brother students. No one had seen him at work. His result was the most perfect copy, as far as light and shade went, but in *pea-green*. He finally became an engraver."

Color names the color-blind learn in various ways to use as we do, and this has heretofore greatly assisted them in escaping detection. And in this way they even now escape, since, in spite of the warnings years ago of Goethe and Helmholtz, that asking them the names of colors would simply drive both parties crazy, there are many whose official duty should teach them better, who still cannot get rid of the idea that they can find out how another person sees colors by simply asking them the color-names of objects. Every one who has the slightest knowledge of this subject and any experience at all, now admits that attempting to test the color sense by asking the names of colors



is simply ridiculous. By such examination the normal-eyed can be shown to be color-blind as readily as the color-blind proved to be normal-eyed. This is equally true of colored objects by reflected light and colored objects by transmitted light, viz., lanterns, &c.

Now, the only way we can compare *mental notes* with another person is by what he says or what he does; that is, by the tongue or by his expression through muscular action. It being certain that we cannot find out how a color impresses another person's brain by what his tongue tells us, we must appeal to the muscular sense, we must cause him to do something with his hand, for instance, which will prove that the impression of the color on his brain is the same as ours or not. Therefore it is that any proper test must depend on this *principle of comparison*.

*Comparison tests* are numerous, but vary greatly in their simplicity or practicability. For the purposes of the medical officers of the Department this board is concerned with the test which must be absolutely sure, rapid of application, and the apparatus inexpensive. For a description of all the various tests for color-blindness, I must refer to my Manual. I will here only exhibit and explain to the board some of the principal ones, including those adopted as standards by the rules of the State Board of Health of Connecticut.

*Wainow's disk* has a centre of one-half each black and white, and outside these are concentric circles, each of which is composed of equal parts of two of the three primary colors—red, green, and violet. While it revolves rapidly the centre is gray, and the concentric rings have definite colors to our eyes, while to the person who is blind to the color not represented in the ring, this ring may appear like the centre, namely, grayish.

*Simultaneous contrast tests* may be varied. I will show but a few. I have bent a piece of white card-board to a right angle and fastened to the adjacent surfaces a little square of black cloth. Now, holding a piece of colored glass with one edge resting in the angle of the paper, about dividing the right angle made by the card-board, and looking down from above, we shall see the reflection of the vertically placed black square of the color of the glass, but the horizontally placed one will appear to us of the complementary color of the glass. Now this phenomenon does not occur to the color-blind.

*Stilling's cards*, here before you, are letters, numbers, or figures printed in squares on a ground of squares, the colors of the letters, &c., and the ground-work being those which the color-blind confuse. Hence they cannot see to read the letters or discern the figures.

*Pflüger's test* is, as you see, also one of simultaneous contrast. On colored pages letters and numbers are printed in black and gray. When the page is covered with tissue paper the color-blind cannot see these letters or figures when the normal-eyed can. This pamphlet, thus arranged, is a practical test used on the Swiss railroads by Professor Pflüger, of Berne.

*Holmgren's comparison test* with the worsteds the board all know of. As is seen, the selection of colors, the numbers of each, &c., are not arbitrary, but must be carefully chosen. I have arranged with a dealer in worsteds to always supply standard sets, as he does for some of the Departments of the Government. The choice of the *green, purple, and red* test worsteds is of importance, and examiners have been no little annoyed and perplexed by not having the right ones to work with.

[Dr. Jeffries then described the worsted test, referring to his Manual for more detailed explanation. Its *seeming* simplicity was dwelt on, and the consequent danger of any one not most thoroughly posted both in theory and practice, making most fatal mistakes, finding color-blindness where it did not really exist, and not detecting it where present. The test was most perfect, but never could be understood too well. He described how ridiculously it had been misused by railroad officials and others.]

*Daae's* test is copied from Holmgren's. On a card in book form are arranged rows of little squares of worked worsteds. Some rows are correct, namely, arranged from the darker to lighter of the same color. Others are arranged of the colors the color-blind especially confound, and they will say when asked that *these* rows are correct. It is arranged to detect red, green, and violet-blindness.

*Donders' worsted test* consists, as you see, of a series of little pieces of wood, on which are wound colored worsteds. By testing a large number of color-blind, he found just what colors they confounded, and he winds one of them on the stock, letting the *other* color come in as a single thread once or twice in the row. Now, these two colors looking alike to the color-blind, they cannot see any difference, and cannot say that there are any or how many bands of a different color or appearance from the rest of the stock. The sticks, as I show, are arranged to detect the three forms of color-blindness—red, green, and violet-blindness.

The *quantitative measure of color-blindness* is very important. The defect exists in all degrees; and, as a certain amount may not prevent persons acting in some capacities, the exact determination of the existing chromatic loss becomes very necessary. For this purpose various methods have been devised, based upon the several principles of color-perception which have been described or alluded to. These are in the Commetieut rules.

*Holmgren's method, with colored shadows*, I regret not being able to exhibit to you, as the apparatus is too cumbersome to be easily transported. It is described in my United States Manual. In the centre is a round-wicked petroleum lamp; from the stand project two horizontal arms; on one is the colored glass before the light, the pencil to cast a shadow, and the white porcelain on which it is cast; on the other arm is the mirror, by reflection from which another shadow is cast on the porcelain; the mirror is movable towards and from the lamp. At a certain distance the shadows will appear of the same brightness to the normal eye, and we measure the amount of color-blindness by the difference in distance of lamp and mirror requisite to cause the two shadows to seem equally bright. This is one of the "control methods" used by Professor Holmgren on the Swedish railroads.

*Donders' method of quantitatively determining the color perception by reflected light*, is by placing these colored disks, from one to twenty millimetres in diameter, on a surface of black velvet hung on the wall. On approaching slowly a small colored object, the normal eye detects the color but little later than he sees the light. The person who has any loss of the chromatic sense, that is in any degree color-blind, sees the color much later than he sees the reflected light. On this is based the method of examination. Bright saturated colors, one millimetre in diameter, when placed on black velvet in a good light, will be seen by an eye with normal visual acuteness at a distance of five metres.

Professor Donders says: "It is interesting to observe how the examined gradually passes from doubt to certainty. We show him a single disk at five metres distance; he sees the little disk, but not its color; a step nearer, and he ventures to call it 'red;' another step, and he doubtfully says, 'no, green.' Finally he says 'red' again, and at last decides more positively for this color. Just when he became certain is readily determined. Or, we put a number of the disks of varying diameters together on the large piece of velvet, and pointing to each with a stick, ask its color quickly. With partial color sense, it readily appears how, in approaching, first the larger disks and then the smaller are rightly named; whilst, with less color-perception, only the larger are told close to; and when there is complete absence, the color of even these is not recognized. We may thus determine the *numerical degree of color-blindness* with sufficient accuracy."

*Donders' method of quantitatively determining color perception by transmitted light*, is by the apparatus before you, used on the railroads in Holland. The light is from a candle, such as is employed to determine the candle-power of gas. This is placed behind a blackened wooden screen, in which is an opening, twenty-five millimetres in diameter, covered with ground glass; in front of this hole a rotating metal disk is arranged, pierced with holes, 1, 2, 5, 15, and 20 millimetres in diameter; just behind the opening in the screen is a rotating disk, with holes—one clear, the others containing red and green signal-lantern glass, as also other colors—which we can, by turning, bring in front of the hole in the screen; the candle is arranged to slide along a scale, thereby giving us its distance from the screen; the room is partly darkened, and otherwise the examination is conducted in the same way as in the reflected light. From the distance at which the candle is from the screen, the size of the hole necessary in the screen, and the distance of the person examined from the screen, we may calculate just what his *degree of chromatic sense or color-blindness* is. For the formula for this and further description, I would refer to my Manual.

Now as I turn the disk to change the color of the light and vary the size of the opening in the screen, the members of the board see how perfectly we imitate the conditions of seeing the colored signals on the railroads as well as the port and starboard lights. A spot of colored light is presented to the eye just as a red or green light appears to the pilot's eye on the water. As soon as seen by the normal eye the color is instantly recognized. Not so with the pilot whose color sense is in *any degree* less than the normal eye. If partially defective, he may finally *hit* on the color when he has approached it, perhaps too near to avoid a collision. If more defective, he will decide instantly *wrongly*, and cause an accident; and how many have thus occurred, and how many will occur before defective sight for form *and* color absolutely prevents a pilot being licensed or *relicensed*?

As color-blind engineers escape accident by fortunate guessing and assistance from familiarity with the surroundings, &c., so the color-blind pilot has escaped by his familiarity with the surroundings. The direction of the wind tells him which way the sailing-vessel *ought* to be moving, and therefore which light *ought* to be towards him. The position of the steamer on the river, the recognition of direction by the dimly-seen outline, a knowledge of a certain vessel or steamer likely to be met with just at this point, and many extraneous circumstances help the color-blind to rightly *guess* which light it is he sees. But how

often are all these extraneous conditions absent for the pilot or the railroad engineer, when, from the color of light alone, *instantaneous* recognition of port or starboard danger or safety must be made to save collision, and which recognition is so certain for the normal eye that the lack of it can hardly be believed?

Now, this apparatus of Professor Donders, in practical use in Holland, and directed by the Connecticut rules, enables us to exactly imitate the condition of seeing colored signals when there are no *extraneous circumstances to help the decision of the pilot or engineer*. If there is any value in the use of colored signals, then certainly there is danger in allowing those who cannot distinguish them by *their color* to steer our vessels or run our locomotives. The testing color-blind pilots or railroad employes who have been long in service, and fortunately for us escaped any very serious collisions, &c., is a very interesting psychological study. As they cannot see their mistakes, they cannot believe in them. The red or green-blind see blue and yellow as we do; therefore, by showing them two bright worsteds of these colors together, and telling them that in their examination they made as marked mistakes as to class these yellow and blue *as the same*, gives them, if they will believe us, some little conception of the gravity of their defect. But seeing is said to be believing, and as they cannot see as we do, they are not likely to believe as we do, *since such belief means loss of occupation*.

Hence, we see at this time the great value of Donders' apparatus. By it the medical examiner can perfectly prove to the interested laity, or inspectors, the pilot's employers or friends, just how he is defective. Nothing is more convincing than the witnessing such an examination, properly conducted. The most skeptical have always admitted the danger, which they could not before appreciate, and which satisfied them so thoroughly that they never asked for further tests with signal-lanterns, &c. But a *misuse* of this test, as, in fact, of any, may equally perplex the medical examiner, render him doubtful of his diagnosis, cause in the laity suspicion of the whole question of the existence of defect or danger from it, and confirm the examined in his belief that he *does* see colors as the normal-eyed. All tests, therefore, must, in justice to the examined, be applied only by those thoroughly competent, whose education enables them to learn them and perfectly understand them when described by the expert.

I would call the attention of the board to an addition I have made to Donders' apparatus, by which, as you see, I can interpose a neutral-colored (London smoke, so-called, used for spectacles) glass, which will simply darken the *colored* light or the white light. Now it will be remembered that red or green colors make a light darker to a color-blind in proportion to the amount of his defect and the depth of the pigment. Hence, when he sees a white light become darker by interposing a smoke-glass, he immediately concludes that it is colored, and says *red* or *green*, according to circumstances. So darkening a pale-green glass will make it seem the same as red to him, and rendering a red one brighter will make it appear green to him. I do not know any way officials can be made to appreciate the peculiar danger of the defect better than by this arrangement, which so perfectly exposes the color-blind's exact condition of vision and shows how dangerous it is. When we remember that a slightly-smoky lantern, a little rain or fog or sleet, a dirty glass, or blurred eyesight from fatigue, exposure, or stimulants, cause the color-blind to mistake the signals, by changing their

usual condition and relative *brightness*, by which alone they decide, then we can realize that, however well they may apparently guess at colored signal-lights close-to, they are most dangerous on the look-out, or in command, or at the wheel. This use of London-smoked glass to test the color-blind must, of course, be thoroughly understood, and the principle of its application. When thus understandingly employed, it is a great help to the expert in proving the defect to the interested laity.

But now to reply to a member of the board, who says: "You have shown us all these different tests by various experts, each one of whom probably thinks his is the best; how are we to decide as to their relative merits?" &c. The several ways of examining which have been exhibited are all *control tests*, to fortify the result obtained by the first and simplest method, namely, Holmgren's worsteds. There is no question of one being better than the other. Except for determining the *amount* of color-blindness, they are not needed. Wherever they show color-blindness, the Holmgren test will do it in infinitely less time. The several Government Departments do not require them, as they have not yet decided on the standard amount of color perception requisite. This renders it all the more necessary that the examiner should be very familiar with the worsted-test and have thoroughly mastered it, which even Prof. Holmgren says cannot be done without patient, intelligent study and practical experience. It has been greatly to the credit of the value of the method, that they have succeeded so well with it. This is shown in the annual report of the Supervising Surgeon-General. Inability on the part of the laity to conceive it possible that such a seemingly common-place test as the worsteds really at once pointed out the dangerous pilot or engineer, and the necessity of deciding the amount of color-blindness, have called for these additional quantitative and control tests. But the examiner must understand them thoroughly, and be competent to explain them in exhibiting the defect of the color-blind he is testing by them.

*Visual acuteness*, or the power of form perception, is tested by the same means all over the world, namely, the ability to read letters or distinguish forms of certain sizes at certain distances under the same circumstances of illumination. *Normal visual power* has been decided by the average of hundreds of thousands of normal eyes. It is to be able to read these test-letters at twenty feet; of course the eye, if necessary, to be fitted with the glasses it may need from being near-sighted, over-sighted, or astigmatic, &c. The standard of normal vision is undoubtedly rather too low than too high. In the Navy and Army a definite standard is required in recruits. No definite one is ordered for pilots, as certainly ought to be. The examination of the eyes and the testing the vision is, by the Treasury orders, left to the medical officer, as he alone can, when the vision is defective, examine the interior of the eye and determine the cause of such defect, and whether, as with cataract, &c., it is progressive. So, also, he alone can say whether there is granular lids, the results of specific or other disease, liable to cause future trouble, and so on. It is only he, and he only when he understands, who can detect the cause of failing vision *for distance*, which comes with increasing years, and can only be remedied with glasses. This cause is the very common defect known as over-sightedness, the eyeball being just the reverse from near-sightedness, *too short*. This de-

fect is most deceptive to the laity, as the ophthalmic surgeon has daily proof of in his work of remedying it by glasses. It is, no doubt, a potent and latent cause of railroad accidents.

I have thus briefly alluded to visual acuteness and *normal vision* to show the necessity of a standard being decided on to govern the medical officers in their examinations, which can be carried out by them alone by proper tests and ophthalmic instruments. There seems to be no desire on the part of the Department, as has been the case with reference to the railroads, to take these examinations out of the hands of medical men. Some standard to govern all medical officers' rulings is called for in justice to both them and the examined. Very likely such standard has been left undetermined in view of an international one being adopted which the Department could be governed by.

I have shown how color-blindness can be detected and the proof of its danger made apparent to all, and explained why the tests for it cannot be carried out in justice to the examined or to the community, by those not thoroughly competent, as medical men only are. I will now turn directly to the explanation of why the two following orders are not fair to the examined and the community:

CIRCULAR.

*Modification of Department Circular No. 14, relating to Examination of Pilots for Color-Blindness.*

1880.  
Department No. 19. }  
Steamboat Inspection. }

TREASURY DEPARTMENT,  
Washington, D. C., March 9, 1880.

To the SUPERVISING AND LOCAL INSPECTORS OF STEAM-VESSELS:

In view of the expense and hardship likely to accrue to pilots living at points remote from stations of the Revenue Marine-Hospital Service, in visiting such stations for the purpose of being examined as to color-blindness, as required by the amendment to Rule 47, Rules and Regulations of the Board of Supervising Inspectors, Department circular No. 14, dated February 17, 1880, is hereby so modified as to allow pilots employed at places remote from a marine-hospital station to be examined by any respectable resident physician, whose certificate that such pilot is exempt from the disease known as color-blindness shall accompany the license and oath of office of such officer when sent to any board of local inspectors for renewal of his license in the manner provided in Rule 42, Rules and Regulations. Upon the receipt of the certificate a license shall be issued the same as though said examination had been made by a marine-hospital surgeon. This modification is not to be applied to applicants for original licenses; they, in all cases, must be examined in the manner provided in circular No. 14.

A second visual examination will not be required in any case, and inspectors will therefore retain all certificates upon their permanent files for reference in cases of applications for renewal of licenses.

JOHN SHERMAN,  
*Secretary.*

## CIRCULAR.

*Pilots Incompletely Color-Blind.*

1880.  
Department No. 46. }  
Steamboat Inspection. }

TREASURY DEPARTMENT,  
Washington, D. C., May 20, 1880.

Local inspectors of steam-vessels are hereby authorized to examine with the colored signal-lights all pilots applying for a *renewal* of license who have been reported by the examining-surgeon as only *incompletely* color-blind; and if the inspectors are satisfied, after such examination, that said pilots can sufficiently distinguish the colored signal-lights used on steam-vessels, it will be within their discretion to renew the licenses.

Local inspectors will report in detail to the Supervising Inspector-General of Steam-Vessels all examinations made under the provisions of this circular, and accompany their reports with copies of the examining-surgeons' reports. Local inspectors will make requisitions upon the Department for authority to purchase the signal-lanterns necessary for the above-mentioned examinations, stating the cost of the same in their requisitions.

JOHN SHERMAN,  
*Secretary.*

From what I have said, it will, I think, be readily seen that trusting the examination of the eyes to any "respectable resident physician" is simply useless. The reason given in Circular 19 is, that it is a hardship for a pilot to travel any great distance to where a marine-hospital surgeon is stationed. But is it not sacrificing the community to the individual, to allow such a pilot as that of the tug "Lumberman" to kill the people and destroy property? There is not one chance in a hundred that in an out-of-the-way place where a pilot would apply to any "resident physician," that the latter would know anything about color-blindness, even if he had ever heard of it. He would have no apparatus to test by or book of instructions to guide him, such as are put in the hands of the medical officers of the Marine-Hospital Service to be studied and used. He would be more likely than not to call a pilot color-blind from pure ignorance, and, if not honest, might be readily *persuaded* out of the belief. There is, of course, no surety and no hold on the physician. Even the surgeons connected with the European railroads, and hence men of good medical attainments, wholly failed, although supplied with proper apparatus, until they had been thoroughly taught by the experts in this sort of work. As a matter of fact physicians and surgeons have left the whole subject of color-blindness and its detection, &c., to the specialists, ophthalmic surgeons, whose particular studies enable them to take up the question both theoretically and practically in an understanding manner. From personal knowledge I know how difficult it has been for the medical officers of the several departments of the Government to do justice to themselves and to the examined with these tests which have been necessarily put in their hands. As I said in my Manual, they can learn, and are now doing so, of course, often under great disadvantages, from lack of being able to consult with others and learn *de visu*, which is here of such great value. For these very reasons the railroad surgeons in Sweden were all sent to Upsala, where Professor Holmgren could teach them practically and scientifically how to test.

"A second visual examination will not be required in any case," according to Circular 19. The facts which I have given in reference to *acquired* color-blindness, from injury, from disease, from alcohol, and from tobacco, are, I think, sufficient proof of the need of testing the color-sense at least as often as a license is renewed. Most certainly the eyesight, as to form, should be tested as often as that, which, with the testing for color sense, can all be done thoroughly in a few moments by the medical officer of the department, who alone should be intrusted with it. The laity cannot do this; it is a medical examination, for medical men to carry out.

I have said that a person born color-blind dies so, and that it cannot be altered or alleviated. So far, therefore, as congenital color-blindness is concerned, one examination would be sufficient; but the question of acquired color-blindness must never be forgotten or ignored, and the need of testing for visual power at least once a year is absolutely necessary. Ophthalmic surgeons know only too well how gradually-failing sight, from cataract or disease, may not be recognized even by the patient himself, and never be known or detected except by their methods of examining the eyes.

*Incompletely color-blind pilots* are, by Circular No. 46, taken out of the hands of the medical officer, and allowed to be tested by the local inspector with colored signal-lights.

The Supervising Inspector-General says, in his annual report: "The last circular was issued because it was deemed but a simple act of justice that pilots of many years' experience, without accident of any kind, should have the fullest opportunity consistent with the public safety to prove themselves competent to continue in the exercise of the duties of the profession in which they have been educated."

Now, the color-blind pilot of the tug "Lumberman," who caused the death of ten people and the loss of property, &c., might perfectly well have been just such a case, namely, one that the medical officer would record, in accordance with his instructions, "incompletely color-blind," and hence fallen to the local inspector to decide on, who, by the tests he is directed to use, would pronounce him perfectly safe to be relicensed.

It is necessary, first, to explain to the board what "incomplete color-blindness" is. It is to be remembered that the defect exists in all degrees, and none of the Government departments have yet decided the amount permissible in any given case, &c. By referring to page 40 of the United States Manual, it will be seen that Professor Holmgren proposes to "classify the different kinds of color-blindness under especial heads, to be able the better to grasp the whole." He says:

"We might, indeed, divide this blindness into congenital and acquired; but, as we are concerned alone with congenital color-blindness, the division is as follows:

"I. Total color-blindness, in which the faculty of perceiving colors is absolutely wanting, and where the visual sense, consequently, can only perceive the difference between darkness and light, as well as the different degrees of intensity of light." [Several such cases are lately reported.]

"II. Partial color-blindness, in which the faculty of certain perceptions of color, but not of all, is wanting. It is subdivided into—

"1st. Complete color-blindness, in which one of the three fundamental sensations, one of the perceptive organs of color in the retina,



is wanting; and in which, consequently, the colored visual field has but two ranges. This group includes three kinds, namely:

“(a.) Red-blindness.

“(b.) Green-blindness.

“(c.) Violet-blindness.

“2d. Incomplete color-blindness, where one of the three kinds of elements, or perhaps all, are inferior in excitability or in numbers to those of the normal chromatic sense. This group includes the whole of a series of different forms and degrees, a part of which, the superior degrees, which might be called *incomplete red-blindness* and *incomplete green-blindness*, (and *incomplete violet-blindness*,) constitutes the transitions to the corresponding kinds of complete color-blindness; and another part of which—the inferior degrees, which we call a feeble *chromatic sense*—constitutes the transition to the normal sense of colors. This classification is quite practical and conformable to experience. We know no classification which, though distinguishing accurately between the different essential forms of a defective sense of colors, draws a surer, more decided, and more practical limit between the defective sense of colors and the normal sense.”

Now, till we have some better, or more precise, or more simple, these are the expressions and these are the terms the specialist and the expert must use in describing or recording his cases, namely, the condition of the examined, just as we must record the examined as being near-sighted, or over-sighted, or astigmatic, or having vision one-half, &c. They are technical terms connected with a technical subject. It is not the fault of the subject or of the medical examiners that the laity do not thoroughly understand their use or significance. Much dust has been thrown into the eyes of the community and of those in official position desirous of doing their duty towards the community by ignorant and wily persons using these terms expressing the various kinds and degrees of color-blindness in a totally perverted and false way, with the purpose of deception and with the view of showing the defect to be but a great rarity, and by no means dangerous, &c.

I would illustrate my point by saying that if, after examination by the various tests I have shown, I should report an engineer or a pilot as *incompletely* color-blind, it by no means is to be understood that I indorse that man as better or more safe than one I report as *completely* red or green-blind. In fact, I do not hesitate to say that I regard partial or incomplete color-blindness as *more* dangerous. For instance, a medical officer of the Navy, inspecting recruits, told me that, with any apparatus formerly supplied him, he could not be proved to be at all deficient as to colors, yet that, at a distance, when he *could* recognize the red port-light, he could *not* distinguish the green starboard-light from the white masthead-light. Testing him with the worsteds, I found that he was partially green-blind, and would be recorded simply as “incompletely color-blind.” Nowhere under the United States Government is it yet required to record the exact *amount* of chromatic defect numerically, as we record the amount of visual power for form numerically, *e. g.*, vision, two-thirds normal, &c. Hence, no apparatus is put in the hands of United States medical officers to measure color-blindness by other than the decision above spoken of, decided by Holmgren's worsted test. A definite amount is required by the Connecticut laws, and the apparatus I have shown you is designated as the method of determining it accurately. The medical officer I speak of

stated most freely that he would be most dangerous on the watch, all the more, as he would *sometimes* be right. Such a man would be sure to escape detection except by thorough tests in competent hands. The completely defective generally give it up, or rely on some one else; the partially color-blind, being often right, are only too firmly convinced that they always are, and readily deceive those about them into the idea that at the most they are only a little careless or inattentive. Red and green lights, *close by*, they distinguish; but at a distance, when the normal eye easily and instantaneously recognizes them, the color is gone, or becomes doubtful; hence, the peculiar danger.

The truth is, that, both on the railroads and on the ocean, each and every degree of chromatic defect is dangerous to life and property, and I might almost say, in inverse ratio to the amount, because the lesser degrees readily escape detection, and go on with the official stamp or sanction of their harmlessness. Experience on the railroads has proved this most conclusively. I believe the time will come when the community will demand absolute freedom from color-blindness in railroad employes and mariners.

The local inspectors or any of the laity, if they attempted to test by the signal-lights even those who were found by the surgeons *completely* color-blind, would, perhaps, equally often come to the conclusion that such were not defective or dangerous, and be perfectly willing to *re-license* them, even without the pressure spoken of in the reports of the surgeons of the department. Still more likely would they be to assure themselves that the partially color-blind were either not so, or if so, scientifically, as is often said with a sneer, yet perfectly safe and trustworthy as pilots. Now, then, partially defective men, who either see signal-lights when near enough, and when in a room guess at them almost always correctly, are precisely those who are dangerous; and local inspectors testing them with signal-lights, and giving their official sanction to the license, only renders them more dangerous, since then their employers are confirmed in the belief of their freedom from defect of any kind.

A competent medical examiner will with certainty very quickly detect any degree of color-blindness by Holmgren's worsted test, and he can equally well show, by proper apparatus, that such blindness is dangerous. Testing with signal-lights will not show this danger, and this is the special reason why I appear at this time before this board. Nothing seems more self-evident than that the way to find out a man's color sense and his capacity for reading colored signals is to put up the signal-lights and ask him what he sees. Upon this very naturally is based the Circular No. 46, allowing local inspectors to test with signal-lights. The same mistake has been made by other boards, and without the good excuse this board has, that it was acting to the best of its knowledge and ability in yielding to the pressure to retain partially-defective pilots. It could not accept unchallenged the assertion and opinions of the Medical department in the face of such seemingly common-sense ideas, that to take a pilot out and ask him the names of the passing colored lights, or to hold up signal-lights a short distance off and do the same, was not the truest, fairest, and readiest way of finding out his color perception.

I am here, as I said, to disprove this, which is thoroughly discussed and shown in my Manual. If I do not succeed in convincing this board it will be simply from my lack of properly presenting the subject.

Before discussing the general question of the uselessness of testing the color sense by lanterns, I would call the board's attention to some very practical points. The local inspectors are provided with signal-lights; the precise kind and standard are not stated or defined. Now, in reality, the glass varies very much. It will be remembered that the red or green-blind see yellow and blue as we do. Now, here, directly from the manufactory, is a very strong *bluish-green* starboard-light that any color-blind would see and recognize the color in it, namely, the *blue*. He would, of course, call it the starboard-light or green. The name is nothing; he calls it what we do, green; and here is another *starboard-light* which is a pale *yellowish-green*; the yellow in this tells him that it is also what he is to call *green* when asked to name it, and he does so unhesitatingly. Any light differing from these two he equally unhesitatingly calls *red*, in which he, of course, will be right. Now, practically, this is what frequently occurs as told me by the manufacturers. A shipmaster buys the dark greenish-blue, and as it gives so very little light it is complained of, and he comes back with his complaint to the seller, who then substitutes the pale yellowish-green. This is, however, soon returned, and complaint made that it does not look different from an ordinary white light, and the exchange is again made for the dark bluish-green, &c. Now the railroad lights vary in precisely the same way, and officials have been puzzled by finding employes who were by experts detected as color-blind, naming, when close enough, (this is the point,) the colored signals (*bluish-green* and pale *yellowish-green*) apparently quite correctly, of course calling all else shown *red*, as it would, of course, be.

[A member of the board here asserted that any vessel using such a light as the bluish-green one shown by Dr. Jeffries would be liable under the law. But the Inspector-General replied that this was not the case, and that the two so different starboard-lights exhibited would equally well meet all the present legal requirements.]

Thus it will be seen that a local inspector provided with certain signal-glasses would never find a color-blind pilot, and quite readily convince himself and the pilot and the *persuasive friends* that the Department orders, Holmgren's test, and even the existence of color-blindness, were all scientific refinements of no practical meaning or value; and, as a Chicago paper seriously says, "that the suggester of this whole movement, &c., ought to be put in prison and the Government indicted by the oppressed color-blind pilot."

Any test by naming colors has been shown to be simply ridiculous, yet any examination by signal-lights must of course be by requiring the examined to say what he sees. Every time he fails it must be put down against him, and, if he has to correct himself, it must be a cause of suspicion. Moreover, whenever the true color-blind guesses rightly, which he may do every time, as it is only between *two colors*, it is to his credit in proving him *not* color-blind. The whole thing will be a mere play of wits between examined and examiner, as unfair for one as the other. I myself now feel pretty familiar with this peculiar chromatic defect and its manifestation, yet I do not hesitate to say that if I was forced to use only signal-lanterns in detecting it I would refuse to attempt to give an opinion. All scientific experts who have had practical experience entirely agree with me in this. There is no difference of opinion. The Supervising Surgeon-General well says, in his Annual Report, p. 21: "When signal-lights are proposed as tests for

color-blindness in opposition to the united opinions of the best informed ophthalmologists in Europe and America, it seems to be assumed that the medical examiner has a peculiar and special interest in the rejection of the candidate. This assumption needs no refutation."

I must be allowed here to read from my Manual, p. 183, what a very *practised* scientific expert, Professor Holmgren, says in reference to testing railroad employés with lanterns, since of course the same applies to testing with signal-lights:

"The great majority of people are inclined to believe that the best method of testing the railroad *personnel* for color-blindness would be the use of the signals employed, namely, the lanterns and flags, as being the most direct, easiest, and suitable. This, to every practical man who has made no speciality of color-blindness, is so obvious as to be a recognized fact. Any method which we are here concerned with has only the aim of preventing the mistaking the signals by the responsible *personnel*. What more simple, is asked with seeming right, than to be assured that the railroad employés can distinguish the signals? What other method can quicker bring us to our desired end? And how can we reach it more readily, since these signals are in use on all railroads? But there is another condition necessary. The examination must not only prove that the men are able to distinguish one, two, or any definite number of lanterns or flags, so or so often, but that they can distinguish all flags and all lanterns under every condition; in a word, that their color sense is as normal as we have a right to demand."

"Testing with lanterns becomes but a hazard between the examiner and examined, where the latter may readily often win, and where the former bears all the loss if the examined afterward fails but once. Of course the examiner is sure to win, if the play is continued long enough, for, if we know beforehand the examined is color-blind, we can sooner or later cause him to make a mistake as to the color of the lanterns. But if we do not know that he is color-blind, and are testing him to decide this, then we shall soon find how unadapted this method is, and how impractical. Naturally, much depends upon just how it is employed. For instance, let us suppose that the usual colored lights are shown to the examined, one after the other, and he is asked their color or meaning, whilst from his answer his color sense is to be decided on. As already shown, the color-blind *may* decide rightly, but we need hardly add that the normal-eyed may fail from carelessness, inattention, or even slip of the tongue. Hence, a color-blind is passed as normal, and the reverse; so in this form the method is not practical. To attain certainty the test must be continued and repeated till the examined's color sense admits of no doubt. But how often must we repeat in order to be sure? How often must mistakes be made in order to prove color-blindness? Or how often may they be made and the defect still be considered not present? It is, of course, impossible to decide these questions. Certainty naturally increases with the number of trials, but the method is still untrustworthy, and it is depending too much on the knowledge and experience of the examiner in reference to color-blindness, to expect a decision from him on such tests."

This, now, is the practical experience of a thorough medical-expert examiner after testing a great many railroad employés. He has been speaking, too, of the question of lantern tests in the hands of medical men specially instructed. If they so utterly fail, as is evident, how would it be possible for *local inspectors* to decide whether there was

color-blindness, and whether it was dangerous, &c. As I said, any degree of color-blindness would very readily pass undetected by them; the most dangerous cases, namely, the *partial* or *incomplete*, would most surely escape and be declared perfectly safe. This, too, by the most honest inspector, uninfluenced by surrounding *pressure*, from which, reports show, none are free.

The same sort of pressure that was applied to this board was brought to bear on the Board of Health of the State of Connecticut, to which, from lack of personal acquaintance with the subject, they also yielded. They allowed defective employes to be tested by what they themselves and their counsel demanded, namely, flags and lanterns at eighty rods. The results from the worsted test were, however, entirely substantiated by these second examinations, an account of which will be given you by Dr. W. H. Carmalt, professor of ophthalmology at Yale University, and who was one of the examiners under the State laws.

[Since the meeting of the board, full reports, &c., have appeared, from which the following are quoted as of special interest:]

Dr. Chamberlain, secretary of the Connecticut State Board of Health, reports in the Boston Medical and Surgical Journal of February 3, 1881, as follows:

"It so happened, however, that, at the outset of the examinations, several engineers, closely connected with the principal officers of one of the most influential roads, were found more or less defective, and others, of greater or less influence politically, were involved. A special appeal, signed by 6,000 or more, including nearly, if not all, railroad presidents and prominent officials, as well as by leading politicians, was presented to the board of health, asking that the methods of examination be entirely changed, and practical tests only employed, such as the flags and lanterns used in signalling. The great cry was that the men be tested by the tools with which they worked, by practical tests—as if those were not practical which ascertained the facts surely, and with the greatest ease and rapidity. In deference to these representations, however, those condemned by the worsted system were allowed a further trial by flags and lanterns, at eighty rods. The results of this were somewhat surprising to the men. Out of twenty-four men examined by Dr. Bacon, and found color-blind by the worsteds, twenty-one failed by flags and lanterns, and the others answered more or less unsatisfactorily. Similar results were obtained by Professor Carmalt, the other examiner."

From the Report of the Connecticut State Board of Health are taken the following:

*Extracts from the Report of Dr. W. T. Bacon, Examining Ophthalmic Surgeon.*

"The whole number examined was 1,029. Of these 4.6 per cent. had color defects and 7.5 per cent. had visual defects.

"Those failing to show satisfactory color perception by the tests enumerated were tried with the flags and lanterns at eighty rods, one or both, in use on the road. Of the twenty-five color-blind to red or green, twenty-four appealed to the flags, and twenty-one of these failed in distinguishing red from green, while three named the colors correctly. In testing with the flags, one of the officers of the road was always

present, and his color perception compared with the employés and with mine. My experience with the flag test has convinced me that it is a wholly unreliable method for the detection of color-blindness, and may have a worse effect than if it had not been used, by giving to the color-blind—who by some chance may have told the colors—a false confidence which he did not before possess. Even those tested by it are not satisfied, as their failure is almost always attributed to some cause, as the light, want of sleep, &c. The three who called the colors correctly were quite blind to green by all the other tests used, and are, in my opinion, equally, if not more, dangerous than those unable to name the flags. Besides its unreliability, the test with flags and lanterns is impracticable when a large number of men are to be tried, and I doubt if the employés of the roads in this State could have been tested by this method during the three months given by the law without great loss of time and inconvenience to the railroad companies."

At a hearing before the railroad committee of the Massachusetts Legislature, February 14, 1881, the following evidence was given by the two gentlemen who appeared before the Board of Inspectors of Steam-Vessels:

"Dr. JEFFRIES. Allow me to say one word to explain to the committee. Those re-examinations with flags and lanterns were what the board of health felt forced to allow from the *pressure* put upon them; and, therefore, their counsel called for that form of examination, and the board of health allowed it; and, as the professor said, the very men that failed by the tests used under the law failed also with the flags and lanterns.

"Professor CARMALT. That is just what I was on the point of saying. The board modified its rules, and directed us to make examinations of those men who failed on our tests with flags and lanterns, and it made certain rules as to how they should be done. I protested against that personally, because I insisted that it was so unreliable; in individual cases I could not make up my mind from that test; that while I was willing to accept the verdict in a mass of cases, that in one individual man whom I found faulty—defective by the test which we regarded as accurate—I would not allow myself to say that that man was free from color-blindness because he was able to tell the flags and lanterns; neither would I say that that man was incompetent or color-blind because he failed on those. But I have made the examinations, however, according as I was instructed; and, with your permission, I will simply, to illustrate that one point, read briefly what the result was. The modified rules, as we called them, were for the protection of old employés who had been on the road for five years or more, and who had shown, as they supposed, their capability for doing their work. The modified rules were not applied to those new employés who had been on the road but a short time, and were still learning their business, and were not regarded as coming under such a regulation. They had not learned, the board said, the peculiar degree of intensity; they had not educated their eyes, if they were color-blind, to determine these little differences, and they would not run the risk with them. I shall come back to that point again, with some other statistics that I have. But, to go on: Of the twenty-eight men whom I found color-blind, eight of them were new employés, and did not come under the test for examination with flags and lanterns; therefore, it leaves twenty whom I

examined in that way; and absolutely not one single man that I examined with the flags and lanterns was able to do it and make the test right. Every one of them made mistakes which, if they had been on their trains, would have been fatal to the train; every one of them. They were of greater or less degree."

The uselessness of lanterns in determining the color sense in comparison with the other tests, especially that by the worsteds, has been equally well shown through the reports of the surgeons of the Marine-Hospital department. And further, the dangerous character of the degree of color-blindness which Circular 46 would have the local inspectors decide on, is equally well shown by these surgeons' reports.

Surgeon Hutton, at Detroit, reports the details of such an examination, and says as to the pilot, "but when tried on lights of which he knew nothing, it confirmed what I decided within five minutes after commencing the first examination, that he was both *green* and *red*-blind, and my diagnosis 'completely color-blind' would stand."

"So far as the test on the river among vessels is concerned, I have maintained that it is no test at all. Vessels' lights have fixed positions. A process of mental calculation, coupled with his knowledge of the relative positions of these lights, enables him to decide the matter, after a little reflection as to the position and course of the vessel, independently of his chromatic sense."

That all these helps will fail the color-blind is shown by the pilot of the tug "Lumberman," who mistook the *green* for *red* light on the steamship "Isaac Bell." Take the case of a man incompletely or partially defective in red and green. The local inspector tests him with lanterns close-to, and, of course, relieves him over the surgeon's head. Now, this man will not see the red storm-signal at a distance, and, losing his vessel thereby, will honestly swear it was not lit. How often is it reported that *red* lights of light-houses were not lit or were not seen, &c.!

All the world over the same experience has been gone through with, namely, the dangerous color-blind have escaped by inadequate methods of testing by those wholly incompetent to make examinations; and this, notwithstanding that Holmgren and Donders, and many other experts, warned against this so plausible and seemingly fair method with the lanterns, &c. Of course, when the lantern test was properly carried out, every man who showed any color-blindness by the worsted test showed by his direct mistakes or uncertainty how dangerous he was. No local inspectors with signal-lights, or any of the uneducated laity, can thus make evident the danger either to themselves or others. This seeming ability of men who have been declared color-blind by medical examiners to see colored signals close-to, or name them *nearly* always correctly, has been the bugbear of all officials. I have, however, never found any officials who would patiently listen to the true explanation, or who saw the color-blind tested by medical examiners, who did not frankly admit that they were mistaken, however they might *act* when subjected to the pressure of surrounding circumstances.

[A member here doubted the report of the examination by Surgeon Hutton. At request of the Supervising Surgeon-General, and in defence of his medical officer, Dr. Jeffries was called upon to read the report, which he did, commenting on it in explanation. He spoke of it in terms of praise, and, after the explanatory discussion, the Board of Inspectors admitted the correctness of Surgeon Hutton's account in

the Annual Report of the Supervising Surgeon-General of the Marine-Hospital Service.]

[Some two hours were then spent by the various members of the board in questioning Dr. Jeffries and Professor Carmalt, in order to satisfy their doubts, or have misunderstandings cleared up, by personal explanations by these gentlemen of the various tests, and especially the apparent contradictory evidence of defect as shown by the worsteds and the signal-lamps as they had been used. The board finally agreed with these gentlemen.]

Dr. Jeffries resumed: Our explanations have shown the great danger which may arise from these examinations being taken out of the hands of the surgeons, and they have equally shown how readily this mistake was made; a mistake most apt to be made at first by almost all officials who have to frame laws and instructions as to these tests, which are so incomprehensible till seen and understood. A desire to see justice done between the community and the pilot alone actuates the criticisms made.

It is with great pleasure that I testify to how far ahead of our mother country, England, this board is in this matter. There the tests of masters and mates for visual power and color-blindness have been left to the examiners in seamanship, of course non-medical men, with a result, reported to Parliament, that is simply ridiculous.

[NOTE.—Reference should be here made to the speech of Hon. B. W. Harris, of Mass., in the U. S. House of Representatives, Feb. 18, 1881, in Congressional Record.]

On the other hand, across the channel in Holland, very strict rules are carefully applied by competent medical men. I quote from my Manual, p. 262, as follows: "Regulations were also proposed to the government by Professor Donders in reference to the navy and merchant marine; and they are now accepted and enforced, as seen from an order in the same official paper, "*Nederlandische Staats-Courant*," of March 3, 1879.

"The Minister of the Department of Industry, Commerce, and the Navy, referring to article 2 of the royal decree of Feb. 17, 1879, (*Staatsblad*, No. 37) in regard to the carrying out directions for the examination for a warrant as mate in the merchant marine, as directed by royal order of May 5, 1877, (*Staatsblad*, No. 98) has decided to require—

"1st. In the test for visual acuteness and color-sensation ordered in the article, the following:

"*a.* Normal vision, without correcting-glasses, with one eye, and at least one-half of normal vision with the other eye.

"*b.* Both eyes must be without manifest hypermetropia of a degree above D 1.00, and in one eye at least normal vision.

"*c.* Visual field not limited in either eye.

"*d.* Eyes and eyelids externally healthy without habitual congestion or irritation.

"*e.* Color perception perfect for transmitted light in one eye, and at least one-half in the other, according to Donders' method.

"2d. The report and declaration of the expert, as required in the above, shall be considered valid for one month only from the time the test is made.

(Signed.)

"TAK VON POORTVLIET.

"GRAVENHAGE, Feb. 27, 1879.



"By the same order three ophthalmic surgeons are appointed as the experts for these examinations in Amsterdam, Rotterdam, and Leenwarden."

How different are these precise regulations, and the means of carrying them out, from the loose methods employed in England. How much better, also, than the regulations of our Treasury Department, in which no definite standard of vision or color-blindness is required, and by which precisely the most dangerous cases, viz., the partially color-blind, are taken out of the medical officer's hands to be immediately *officially* declared not dangerous by the local inspector through his test with lanterns, which never can detect the defect or exhibit the loss of color-sensation.

Repeated notice has been taken of the especial danger on the sea. Dr. Daac, in a lecture, April 10, 1878, before the Medical Society of Christiania, said:

"But how can having rules for the marine of one country only be of avail? On the ocean-vessels from all parts of the world pass each other. When two vessels meet, it will help but little if the officers and crew of but one vessel have normal color perception. If there are color-blind on the other vessel, collision may occur.

"As to the railroads, it is not of such importance that the requirements as to color-blindness should be the same in all countries. If one country has one set of regulations, and another a different one, whilst a third requires no examination, it concerns only the individual country itself. But as to the marine, it is necessary to have an international law."

I follow these sentences in my Manual by saying: "The test for color-blindness now being so simple as to be readily carried out by the surgeons attached to vessels, especially naval medical officers, there can be no great difficulty in having an international commission meet and frame the laws which shall govern all the navies and merchant-marine of the great maritime nations at least. It would then be as readily recognized that every officer and man must be able to perfectly distinguish the red and green lights as to know where they belong and what they mean."

The last conclusion in my Manual is: "An international commission should be called to establish rules for the control of color-blindness on the sea, and the carrying out the same examinations amongst pilots, masters, and crews of steamers and sailing-vessels, in the navies and the merchant-marine."

As the members of the board well know, a petition in favor of such a commission was presented to Congress, referred to the Naval Committee, and most favorably reported on by the introduction of a bill to initiate it by the Executive. This bill may come up at the next session of Congress, if not reached by the present through the petition. Such a commission was strongly favored by the Secretary of the Navy in his annual report for 1880. Its special value to this Board of Supervising Inspectors of Steam-Vessels, all the members can realize. The rules and regulations agreed upon, and the standards of tests and requirements of visual power and color perception, would be a basis for the board to act upon which no pressure could affect, and relieve the individual members of the onus and the responsibility, which has naturally caused them so much time and trouble in their attempts to do justice

to all parties. Such international laws would be gladly adopted and acted on by all maritime powers. The United States, it is trusted, will have the honor of having initiated the commission, the great value and importance of which its own action, proceedings, and final report will amply show.

I would now introduce Dr. W. H. Carmalt, professor of ophthalmology at Yale University, who is one of the medical examiners who tested the railroad employes, and who will give you his practical experience in examining with lanterns.

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REMARKS OF PROFESSOR CARMALT.

MR. PRESIDENT AND GENTLEMEN OF THE BOARD:

I shall attempt to add nothing to the scientific exposition of the question of color-blindness and visual power which Dr. Jeffries has already presented to you. My position as examiner of the railroad employes of the State of Connecticut has, however, given me a familiarity with the objections urged against the law of that State, which, perhaps, will be of assistance to you in making up your minds as to the advisability of a law for the examination of your pilots and the limitations of the tests to be employed.

The question which almost invariably follows every exposition of the Holmgren worsted-test from those who have had to do with signal-lights is about this: "We don't dispute at all that the tests you show us are accurate so far as they are concerned; they do detect what you call color-blindness; but, Doctor, does it follow, and how does it follow, that if a man makes the characteristic errors that you describe, and which he undoubtedly does make, that he is liable also to mistake the signal-lights?" My answer is positive: "He will mistake his signal-lights if you place him and them in the *same relative positions*. If he confessedly cannot *see* any difference between green and slate or gray here, with everything in the way of abundance of light and proximity of object in his favor, he will assuredly be liable to fail when the signals are reduced by distance or atmospheric changes to that minimum of light which the normal eye can determine with precision."

The Donders apparatus, the construction of which Dr. Jeffries has shown you, has proved that the normal eye can see the colors of the different transmitted lights, to distinguish them accurately, through the smallest opening, 1 millimeter ( $\frac{1}{25}$  inch) in diameter, at 5 metres (16½ feet) distance; but that those who fail on the worsted can only see the spot of light, to determine its color, at 10, 5, 3, or 2 feet, as the case may be, depending upon the amount or degree of his color-perception. About ninety-six per cent. of men can make a correct assortment of the Holmgren worsteds; about four per cent. cannot. Ninety-six per cent., more or less, of men can see the color in the spot of light of Donders' apparatus; four per cent., more or less, cannot. The *same* ninety-six per cent. who pass the worsted-test pass successfully the test with Donders' apparatus; the identical four per cent. who fail at the worsted-test make mistakes at the sixteen-foot distance with the Donders apparatus, and are obliged to move up closer to it in order to be sure. Now I insist that the spark of light represents exactly the signal-lights of your vessels when carried off far enough; but the "tests"

which you tell me you apply, and which the incompletely color-blind men of your rules pass successfully, are not one-tenth, nay, one-hundredth, part so severe as the remaining ninety-six per cent. have passed. In fact, they are no tests at all. The test of a man's muscular strength is not whether he can lift 5, 10, or 25 pounds, but whether he can lift, say, 555½ pounds. On that last half-pound of visual force, so to speak, will, in the all-important emergency of fog or narrow channel, depend the lives of perhaps hundreds of persons. Holding the great side-lights, as you do, from fifty feet to half a mile distant from the man, is like the first ten or fifty pounds lifted in the illustration above given. It is no proof or evidence that he can see the same thing accurately at four times the distance; and, even if he does not fail, you must see that he has had an even chance of *guessing* right.

That such men do fail is certain, even on such low tests as were adopted by the Connecticut State Board of Health, on petition of the employes, which was that they should be examined, at eighty rods, by the "flags and lanterns in common use on the road in question." To say nothing of the flags, which varied from a dirty (black) red to a clean white, the lanterns, as appealing more directly to your case, might, by the terms of the rules, vary from the head-light of an engine to the feeble switch-light on a turn-out. The hand-lanterns of conductors, brakemen, &c., have no fixed standard; and, although you are more accurate in your *instructions*, Dr. Jeffries has shown you how variable the intensity of the light must be in passing through the variously manufactured glasses found in the shops of the ship-chandler, &c.

In the examination mentioned, I endeavored, as fairly as I could with the ridiculously inaccurate instruments at my disposal, to get at the man's color-sense, as he would have shown it by the Donders apparatus. To this end, I surrounded the lantern on all sides but one with a black box, so that there should be no side reflection to guide him. On the open (or front) side I passed the slides of colored glasses to represent the different colors of the signals, and then, by a proper system of signalling and clerical assistance, an accurate record was kept, respectively, of the slides I passed before the lanterns, and the answers which the man made to correspond. I used for slides green, red, and smoked glasses of different intensities, made by using the slides respectively single or double. I warned the men, in advance, of what I was going to do; explained to them that there was no "catch" in it; told them they must give the name of the *color*, but if it was simply a light reduced to a dim light by smoked glass to say so and not call it a *color*, and the correct reply would go to their credit. If, however, a dim light was exposed and they gave it the name of a color it was evidence against their proper color-perception. The distance, eighty rods, relative to the size of light used was so short that a person with normal color-perception had no sort of hesitation in naming the colors immediately and promptly. As the rapidity with which the decision is made is of course an element of great practical importance, they were allowed five seconds in which to tell the color, and it was ample; yet, with all the conditions mentioned so strongly in their favor, most of them made errors which, in the first place, were characteristic of the defect, and in the second would have been fatal to the safety of their train if made when on actual duty.

I will not weary you with reading the whole list. Let it be sufficient to give a couple, more or less, of the most characteristic, after, in fair-

ness, stating that some of the men answered all signals correctly; a fact that I could not accept as proof of their normal color-perception because of the inadequacy of the test, just as I regard your examinations as unreliable for the same reason. One man *guessed* straight forward alternately, fourteen times—red, green, red, green, &c., all through his examination, except twice, when he did not venture upon any reply. Another gave all his answers so slowly, that four times out of twelve he failed to answer at all; once he called a smoke-slide (or dim light) a green light, thus failing five times out of twelve at signals of his own selection. This same man, when examined with the flags, was very doubtful where those with normal color-perception had no doubt, and when the flags were exposed to a bright sunlight made some failures in names; when they were carried into the shadow of a brick wall, was utterly unable to see the bright red flag at all—he could not distinguish it from the dull brick wall behind it. Another made the following series:

Dark smoke. . . . . he called Red.  
 Red . . . . . he called Green.  
 Green . . . . . he called Dim White.  
 Deep red. . . . . he called White.  
 Light smoke. . . . . he called Green.  
 Deep red. . . . . he called White.  
 Deep green. . . . . he said, "Don't know."

A fact of prime importance, it seems to me, was shown in the ages of the color-blind engineers and firemen. They were all young men, with one exception; this one was thirty-nine years old. Dr. Jeffries has told you that alcoholism and syphilis will cause color-blindness; this man was notoriously a hard drinker; was intoxicated the first time I examined him, and within a month after my examination was arrested in a bawdy-house. I think, from the character of the mistakes he made, both with the worsteds and the lanterns, that his defect was acquired (it may have been simply exaggerated) in late years. Except this man, all the others were less than thirty-two years of age. The average age of the class being thirty-six and one-fifth years; the average age of the color-blind of that class was just thirty-one years. The conclusion which may safely be drawn from this is, that the color-blind men prove themselves to the satisfaction of their superior officers, for some reason or other, to be incompetent before arriving at the average age of their class. "They make mistakes;" "they are careless fellows;" "confound him! he never looks at his signals!" I respectfully suggest that they *do* look at their signals. They look at them harder and more attentively than any of the others; but, gentlemen, the signals do not convey to their brains the same sensation that they do to ours. If the men with this defect can have a *standard of comparison*, they do fairly well. If they see a green and a red light exposed together, or a white along with either, they can probably tell them correctly, especially if, in addition, the surroundings are such as they are accustomed to, or can observe. If, however, their point of comparison be taken away; if they have absolutely nothing but one single point of light to judge from, they are liable to fail. They have one chance in two of guessing aright, of course. Your "Lumberman" accident is a case in point, and I had an experience which will serve to illustrate the same thing. While examining a squad of color-blind men, as directed by the board

of health, with their colored lanterns, one man undergoing the examination, the remainder, collected together a few feet away, were discussing the lights, which they could see also; some question arose among these last as to a certain light, when one spoke up, saying: "If you want to know how a white light looks, look at the stars." They were *feeling* around for a standard; their comrade gave them the information sought for, the use of which had undoubtedly stood him in good stead in times past, just as it has stood by your color-blind pilots, and will again; but unless you can guarantee to them a star-lit sky, or both signal-lights—and in the latter case no fog, or rain, or snow, to disturb their brilliancy—you are putting them in positions of responsibility entirely beyond their physical powers.

I thank you sincerely, gentlemen, for the attention with which you have listened. I wish you could see that we are presenting to you a problem as capable of demonstration as any you are familiar with in geometry. If the color-blind man puts along with the green worsted a light-brown, or slate, or gray, and, with the brilliant scarlet worsted, a dark-brown, or black, or even dark-green, it is because he *sees* them so, and the old proposition of our school-days—"things which are equal to the same thing, are equal to each other"—comes back to us. The difference between the green and red is, to him, simply the difference between a light and a dark-brown. If you think that is enough for your signal-lights, our errand here has been a fruitless one.

