Report to the Board on color-blindness / by E. Hutchinson.

REPORT

TO THE BOARD ON

COLOR-BLINDNESS.

By E. HUTCHINSON, M. D.

To the Honorable, the Railroad Commissioners of the State of New York:

Gentlemen:—In compliance with your request, I have examined the subject of color-blindness, imperfect vision and deafness, as occurring among railroad men, for the purpose of ascertaining the best methods of protecting the public from the consequences of these defects.

I have the honor to submit the following report:

Color-Blindness.

In 1877, Prof. Frithiof Holmgren, of the University of Upsala, Sweden, published his book on color-blindness in its relation to railroads and navigation. He gave the first great impulse toward the movement to have engineers and pilots, and all others whose duties require them to know color signals by day and night, properly examined as to their color sense. In 1855, Prof. George Wilson, of the University of Edinburgh, wrote a book calling attention to the great need of perfect color sense in railroad employés and sailors, but he did not establish such a perfect method of examination as did Holmgren, nor did he succeed in gaining the interference of any government to carry out his plans. In one instance, that of the Great Northern railway, the company resolved that no person should enter its service who could not prove himself free from any defect of the chromatic sense. This was done after Dr. Mackenzie, of Glas-

gow, had called the attention of one of the directors, Mr. Graham Hutchison, to Prof. Wilson's book. To him, then, the world owes a lasting debt of gratitude, but it was reserved for Prof. Holmgren to make the methods of examination exact and to invent a system which could be put into use by all the governments. After Holmgren had taught many physicians and railroad officials that it was possible to determine those who could not be safely trusted in telling the colors of signals, he found but little trouble in having an order issued by Oscar, King of Sweden, compelling all who were to be employed on railroads, to get a certificate of correct color sense.

The first account of color-blindness was by Mr. Joseph Huddard to Rev. Joseph Priestlly, the great chemist and philosopher, January 15th, 1777, and published in the Phil. Trans. Royal Society. This was the case of Harris, a shoemaker, in Newburyport, England. He was absolutely red-blind and he wondered, when he had found a child's stocking in the street and sought its owner, that the people called it a red stocking. The great English chemist, Dalton, was color-blind and wrote a full description of his case in 1794. Sir John Herschel tested his defective sense and sent him a collection of colored skeins of silk, with instructions to tie together those which appeared to him alike. This list was published in the *Contemporary Review* for May, 1880, in an article by William Pole, F. R. S., and Prof. W. H. Carmalt, of Yale College, says of it, "I first saw that article after I had finished the examination of the railroad employés, and was startled by the identity in the selections made by Dalton, nearly eighty years ago, and now first published, with those that I found to be made by the railroad employés, with Holmgren's worsted test, the modern adaptation of Sir John Herschel's silk skeins. 'He placed together as identical, orange and yellow-green; yellowish pink (salmon color) and yellow-green; green and red and brown; pure blue and violet; green and red-orange; lilac and blue-grey and lavender and light blue and pink; red-orange and brown and orange-brown and light red; red and brown; red and green; green and brown; brown and several varieties of green.'" (*Dichromatism or Color Blindness. New England Medical Monthly, October*, 1881.)

It is not strange that this defect of color sense should have been called "Daltonism," and is so known in France to-day. That there are many persons who cannot tell red from green, or who at least have great difficulty in seeing cherries in the tree, or in picking strawberries from among the green leaves in the field, most persons know

very well. We have all heard of the tailor who sewed a bright green patch in the seat of a red pair of pants and who was astonished when called to task for his mistake. The blunders of color-blind clerks, artists and chemists must be familiar to all intelligent people. As four persons in every one hundred males will confound shades of red and green, those who can see correctly will be very apt to notice the defective ones. If the color-blind cannot tell with certainty the shades of green and red by daylight, they become much more confused when tested at night by colored signals. Bright red and pure green lights strongly illuminated may be recognized by those of imperfect color sense at very short distances, but when the distance is increased, the green and red appear only as shades of white. Old engineers and firemen can frequently guess the colored lights correctly by the comparative dimness, but they cannot see the colors if they are color-blind, and so are very liable to make fatal mistakes. Taking it for granted that such a defect as we have described actually exists, it is proper to explain as briefly and concisely as possible the physiology of the phenomena.

Sir Isaac Newton described seven primitive colors in the solar spectrum: violet, indigo, blue, green, yellow, orange and red, and thought these could not be decomposed. Sir David Brewster argued that these seven could be formed from the three colors: blue, yellow and red. After him Dr. Thomas Young carefully examined the combinations needed to produce the seven colors, and found they could be formed from violet, green and red. This theory was adopted by Prof. H. Helmholtz, of Berlin, in 1858, and to-day it is known by the name of the Young-Helmholtz theory. It fully explains all the facts which interest us in this inquiry. Later, Prof. Hering has asserted that the combination of black and white, and the four principal colors, violet, blue, yellow and green, will produce all the rest. It does not make any difference which theory we adopt, as the results are exactly the same with those who are color-blind.

In the Young-Helmholtz theory it is supposed that white light is composed of the three primary colors, violet, green and red. Dr. Young first announced the undulatory theory of light, and showed that each color had its own number of vibratory waves in every second of time, the violet rays being shorter and moving much more rapidly than the red rays. He also supposed that in the layer of the retina lying next to the dark choroid, where the sensitive rods and cones are situated, terminal nerve filaments were so arranged

that the three colors were recognized, each by its filament. If no light was received into the eye except rays from a red object, the filament sensitive to red gave its message to the brain while the other two were unaffected. If green rays were only received, the nerve for green was excited, and so also for the violet rays. If all the colors in the spectrum are mingled, they produce white light, and white light is the sensation in the retina of the excitation of all the three nerve filaments. By an ingenious diagram Helmholtz has shown that as the mingling of the primary colors in certain proportions produces all the various shades known, so the three terminal nerve filaments in the retina recognize the colors by responding to the excitation produced by the mixture. Violet is produced by its own method of vibration, and is appreciated by its own nerve fibre; blue is the mingling of the violet with green and red rays; green is the mingling of a very small proportion of violet and red rays with the green; yellow is mainly green and red; orange contains more red and less green, and finally red has its own peculiar vibrations.

There are many ways to prove that the human eye has distinct nerve fibres for each of the three colors. To instance one: if we carry a stick of bright red sealing-wax to the edge of the field of vision, by moving it to the extreme right or left, while we look directly in front, it will at a certain point lose its red color, although we still see its form. If a blue object is substituted for the red one, we can see the color plainly in the same position. This shows that at a certain point on the edge of the retina the red filaments are not distributed. In a word, every one is color-blind for red in this part of the eye. It can be easily believed that in some, these filaments are not developed to the normal degree, and that they are insensible to the color vibrations of that particular tint which corresponds to the imperfect nerve fibre. So we may have also a green-blind, or possibly a violet-blind person. If a sufficient period of time were allowed for experiment, one of these imperfect individuals might see and call the color correctly, especially if the source of light was very bright. From what has been said, it will be readily understood, that as the ordinary shades are made up from vibrations of the primary colors, if an individual has one of the nerve filaments corresponding to one of the colors, wanting, he can only see the effects produced by the vibrations in different degrees from those which are perfect. He will not perceive colors as healthy persons do, but will leave out in his description the tint which in him is unable to produce any effect on

studied the most exact tests and who thus enabled oculists, and those instructed by them, to ascertain who were and who were not fitted to be pilots or engineers. The manner of examination is simple. About one hundred and fifty skeins of various but definitely chosen colored worsteds are used and thrown upon a table, and at a little distance the first test skein is laid, a pale green. The men come in together and one is asked to pick out from the heap of worsteds those which look like the test skein, lighter or darker: no names are to be used. If he has a normal color sense, this he can easily and rapidly do. Then, he may be asked to do the same with the purple and red; but if he makes no mistake with the green, he is not color-blind. Suppose, however, that he should place grays, drabs or pale reds by the side of the green, then a defect would be at once proven. The purple skein will now permit the examiner to ascertain if the defect comes under the head of red blindness, as the purple is a mixture of red and blue. If the man does not know red, he will place alongside of the sample bright blues: if he is green-blind, he will place with purple, green or grey. With the red skein he will place browns and greens, if he is red-blind, but if he is green-blind he will select lighter colors. Everything depends upon the promptness and the accuracy of the examined individual in enabling the surgeon to form an estimate of the degree of the defect. Those who are proved color-blind are seen so to be by their companions, and may afterwards be tested by flags or colored lanterns, or by the many corroborative tests known to experts, as Stilling's colored charts and letters, Donder's worsted sticks, Daae'es card, colored glasses, etc. No possible errors can be made by these methods, and there is nothing more positive in science than the results. Great experience and care is, however, needed by the one having the final responsibility in each case, and it is found that sure results cannot be obtained by having the examinations made by men who are not trained to exact scientific work, and who, above all, may possibly be influenced by prejudice or favoritism. On one account particular care has to be observed by the examiner, for it is well known that engineers of long service, who are color-blind, can guess the signals, whether flags or lanterns, correctly, very frequently. This is explained by the great attention given by them to the shades of light, and they will call the brightest signal white, the next brightest green, and the dimmest red. The fallacy of employing ordinary signals as a mode of ascertaining those defective in color

sense is easily understood when it is remembered that the candidate, if color-blind, has an even chance of guessing correctly, and if he makes a mistake he can easily correct it, and so convey the impression that he can tell the colors perfectly well. One color-blind engineer turned his light down quite low to represent what looked red to him, a little higher to represent green, and up to its full extent to look like white. Dirty lanterns and dirty flags will often mislead these men, and their lives and those of the passengers may be sacrificed in consequence.

STATISTICS.

The worsted test in the hands of an expert detects every color-blind person, and absolute practical experience has shown that those so detected fail to see the flag and lantern signals at the necessary distances. In the third annual report of the Connecticut State Board of Health for the year ending November 30, 1880, page 69, Dr. Wm. T. Bacon, of Hartford, Dr. Carmalt's associate examining ophthalmic surgeon, states: "Those failing to show satisfactory color perception by the tests enumerated were tried with 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. * * * * 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."

The percentage of color-blind persons found among railroad men is about that found among all other classes.

The following tables are given by Dr. B. Joy Jeffries in his exhaustive treatise on color-blindness, edition of 1883, pages 142 and 143:

EXAMINERS.	Country.	Number tested.	Color-blind.	Per cent.	Position.
Dr. Fontenay	Denmark ..	2737	82	3.00	Railroad employé.
Dr. Ginti	Austria	1682	42	2.49	Railroad employé.
Dr. Van Reuss.....	Austria	800	19	3.50	Railroad employé.
Dr. Wyrubow	Russia	861	21	2.44	Railroad employé.
Dr. Stilling	Cassel.....	400	24	6.00	Railroad employé.
Prof. Donders.....	Holland....	2203	33	1.43	Railroad employé.
Dr. Krohn.	Finland	1200	60	5.00	Railroad employé.
Dr. Holmgren.....	Sweden	7953	171	2.15	Railroad employé.

EXAMINERS.	State.	Number tested.	Color-blind.	Per cent.	Position.
Dr. Bacon.....	Connecticut ...	1,029	35	3.40	Railroad employé.
Dr. Carmalt.....	" ...	921	28	3.04	Railroad employé.
Dr. Owens.....	Illinois	967	49	5.04	Railroad employé.
Dr. Thomson.....	Pennsylvania..	1,383	55	4.03	Railroad employé.
Dr. Jeffries.....	Massachusetts.	230	10	4.34	Railroad employé.

Dr. Jeffries has examined over 34,000 persons in this country with the result of 4.00 per cent color-blindness in males and about .25 in females. This is about the result obtained in foreign countries. In the annual report for the Marine Hospital Service for the United States, June 20, 1880, Dr. John B. Hamilton, Supervising Surgeon-General, states that up to that date 2,870 pilots had been examined and 64 (2.21 per cent) found to be color-blind. For the fiscal year, 1883, he reports 3 per cent rejected for color-blindness out of a total of 2,886 men examined.

CHANGING SIGNALS.

As very few, if any, persons are color-blind for yellow and blue, it has frequently been proposed to do away with the red and green signals on land and sea and have only the first two colors. This is found not to be practicable, for a blue glass of sufficient intensity of color to make an impression at a distance, cuts off so much light as to be too dim to be seen clearly, and all such signals are only bright points of light and the colors cannot be detected far away. No useful change can be made in the colors of signals in order to give the four imperfect men in every hundred places as pilots or engineers. The ninety-six men who can tell these signals accurately, should be the only ones to whom the public would have to entrust their lives.

PENNSYLVANIA RAILROAD.

Dr. William Thomson, of Philadelphia, is the expert who has under his supervision the visual and hearing power and the color sense of the 35,000 employés of the Pennsylvania railroad, a corporation whose rules and methods are a model for all others in this country. He has arranged a modification of Holmgren's worsted test, which is entrusted to the superintendents or surgeons in the various divisions, and by it those whose color sense is defective can be recognized readily, and can afterwards be tested by him.

The worsteds are numbered in such a manner that the odd num-

bers are attached to the green, purple and red tints like the test colors, and all the grays, browns, yellows and confusion colors generally are attached to even numbers. These numbers are covered up and the stock is locked so that no one can tell the story except the man who has the key.

This method has been found to be just, accurate, easy and practical.

Color-blindness is caused by some diseases of the brain or eye, and by poisoning from alcohol and tobacco. It also may be caused by injuries to the head or nervous system. Night-blindness is sometimes acquired as the result of disease and must be kept in mind by the examining surgeon. These persons can see well by day, but are almost blind after sundown. This condition is among those which are curable.

IMPERFECT VISION.

It will be admitted by all that engineers and pilots should have as good sight as other men in general, and that those who are near-sighted, or far-sighted, or astigmatic, or who have cataract, or opaque spots on the cornea, or eyes damaged by old inflammation, or glaucoma, or atrophy of the optic nerves, or when from any cause the sight is bad, they should not be permitted to occupy posts of responsibility requiring sharp vision. The examinations are readily made by those accustomed to the work, and on the railroad mentioned and in all states and countries where pilots and engineers are examined before they receive licenses, the vision must be found equal to the normal standard.

HEARING.

No other occupation that can be chosen requires that constant strain upon the eyes, ears and brain, that must be used by a locomotive engineer. He not only has to look out ahead of his train, over a clear track, on a clear day, but he must see in rainy, misty or foggy weather, and be able to see all lights and signals on the darkest nights. He is not sitting quietly at his post, watching calmly at his ease for some signal light, but, as is well known, he is in the midst of a horrible din of noises, the roar and jar of his engine and train, the noise of escaping steam, and the rattle of his machinery. Not only has he to be on the look-out, but his ears must be strained to the utmost to hear any unusual sound. He must attend to the signal bell and listen for any noise which would tell him of a broken bolt or accident to the apparatus. He must hear the noise of a torpedo danger signal and be

ready to stop his train instantly, and also listen for the warning whistle of a passing engine. Not only must he see well, but he should also hear well. The exposure to which engineers and firemen are subjected from storm without and furnace heat within, through wet and cold and snow, with the chill of the long tunnel succeeding the heat of the outer air, renders them very liable to diseases of the chest and throat and to various forms of deafness. The catarrhal deafness so common to these men is not that from which danger may often arise, and it is a fact that many persons deaf from this cause hear better in a noisy place than they do where it is still. The peculiar deafness to which engineers are subject involves the inner ear and the acoustic nerve, as in boilermaker's deafness. It is incurable. It is this which makes it so dangerous, as it prevents the recognition of even shrill sounds. Prof. Moos of Heidelberg called the attention of the scientific world to this fact at the International Congress held at Milan in 1880. (Archives of Otology, vol. 9, page 219.)

This subject has been investigated since, and practical experiments have been tried on German railroads, which show that although some accidents have arisen from this cause, still, where the voice can be heard at ten feet, the engineer can hear sufficiently well to recognize sound signals.

CONCLUSION.

To Dr. B. Joy Jeffries, of Boston, the thanks of all citizens are due for his untiring energy in investigating the subject of color-blindness. He, through his valuable book, and in lectures and written articles, has done more than any one else to awaken a public interest in the dangers which arise from this cause. He has succeeded in getting a law passed in Massachusetts requiring the railroad employés to be examined for visual acuteness and color-blindness, and has also been instrumental in having such a law passed in Connecticut. This was repealed by political demagoguery the next year, but not before Prof. Carmalt, of New Haven, and Dr. Bacon, of Hartford, had shown how many men were running trains who were endangering the lives of the public, as well as their own. Dr. Jeffries has also appeared before the board of supervising inspectors of steam vessels, and has succeeded in having a law passed requiring the examination of United States pilots for color-blindness. Dr. Jeffries is doing for this country what Profs. Holmgren and Donders have done for Europe. In Sweden and Norway the government has

ordered the examination of all employés, and the examinations are made also in Belgium, Holland, Prussia, Austria and on most railroads of France and Great Britain. On some of the ocean lines pilots have to be examined and found to have good perception of color before being enrolled.

There is great difficulty in ascertaining accidents which have been caused by color-blindness. Prof. Holmgren's attention was first called to this subject by the railroad accident at Lagerlunda, Sweden, November 15, 1875, which was due to this cause. The case of the color-blind pilot of the tug "Lumberman," which ran into the steamer "Isaac Bell," of Norfolk, in 1875, was reported by the supervising inspector-general of steam vessels, to the treasury department. In this accident, the red light of the opposing vessel was shown to the pilot and he thought it was green; he made the collision, and ten lives were lost.

It is proper to mention that in March, 1878, Profs. J. Delbœuf and W. Spring, of Lille, France, published a very interesting article on the amelioration of color-blindness by looking through certain colored solutions. Prof. Delbœuf was color-blind, and his observations were corrected by his colleague. He found, by looking through a solution of fuchsine, an aniline dye, that red and other colors which he could not detect before, became visible to him. His experiments have been repeated by many scientific men, with the result of proving that some color-blind are really benefited. As to placing such a colored pane of glass or thin solution in front of each color-blind railroad engineer in order to enable him to detect signals, Prof. Javal says: "This correction will therefore be only applicable to those persons, relatively few, whose occupation is such that their infirmity is a positive hindrance, and from these should be excluded railroad employés, pilots, etc., who are color-blind, as such must be absolutely removed from posts where their deficient chromatic sense may cause accidents." (Jeffries on Color-Blindness, 1883, page 136.)

Dr. W. H. Carmalt, in his admirable paper on Dichromatism, already referred to, states that accidents from "mistaken signals" occur almost weekly, and that expert examinations of the vision of the employés after such accidents have never been made in this country (abroad they are made), and that the engineer, who is presumably the one most at fault, is frequently killed.

I hope that I have presented the foregoing facts so clearly as to convince candid men that color-blindness exists; that those who

are unable to distinguish the danger signals most frequently used on land and sea should not be placed in positions where their mistakes may endanger the lives of their fellows; and finally, that legislative action is needed to compel the proper examination of all pilots and railroad employés before they are permitted to practice their respective callings. These examinations should include, of course, the visual power and hearing as well as the perception of colors, and in my opinion, the men should be re-examined after any severe illness, or if any suspicion should arise that they suffer from tobacco or alcohol poisoning, or from any disease of the eyes.

I append a copy of the law as it stands at present on the statute books of Massachusetts.

AN ACT relative to the employment by railroad companies of persons affected with defective sight or color-blindness.

Be it enacted, etc., as follows:

SECTION 1. No railroad company shall employ or keep in its employment any person in a position which requires him to distinguish form or color signals, unless such person has been examined for color-blindness or other defective sight, by some competent person employed by the railroad company, and has received a certificate that he is not disqualified for such position by color-blindness or other defective sight.

§ 2. A railroad company shall be liable to a fine of one hundred dollars for each violation of the preceding section.

Of this law, Dr. Jeffries says, page 280: "It is quite imperfect in not protecting all parties concerned, and in fact is 'but a recognition of the rights of the community.' No standards of color perception and visual power are required, and no provision that the examinations shall be made by persons whose competency is beyond question." It is but just to Dr. Jeffries, as the pioneer of the movement in this country, to state that what he has claimed as necessary, and has always argued for, is simply the legal enactment of standard requirements of visual power and the color sense, adjusted to the several positions of employés, these standard requirements to be tested for by standard methods, through competent experts legally appointed.

EDWIN HUTCHINSON.