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DIAGNOSTIC TESTS OF COLOR DEFECTIVE VISION

Annotated Bibliography, 1956–66

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FOREWORD

This annotated bibliography of recent literature on diagnostic tests for color defect is presented as a scientific service of the Civil Aeromedical Institute. The aims of the publication are: (a) to provide interested researchers with source material and (b) to provide medical examiners with material relevant to the diagnosis of color defect.

In achieving these aims, bibliographic listings such as the present one are necessarily limited in scope. However the survey is not limited to the years listed. Papers from years prior to 1956 concerning tests that are currently available commercially have been included and one reference is included from 1967. No attempt is made to evaluate the scientific worth of a given article.

References 23, 24, and 83 have recently been translated. Copies of the translations of these papers only may be obtained by writing to: Medical Librarian, HQ-640, Federal Aviation Administration, Washington, D.C. 20553. Please provide the librarian with the complete reference information.

DIAGNOSTIC TESTS OF COLOR DEFECTIVE VISION

Annotated Bibliography, 1956–1966

1. BAILEY, R. W. Color vision deficiencies in army fliers. USAARU Report No. 65–2. April, 1965, Fort Rucker, Alabama.

This paper deals with a review of some color tests and a testing procedure employed to determine the number of color anomalous fliers in army aviation. Data collected indicate that the color requirements may be unnecessary and that a new approach is overdue.

2. BAKER, H. D. Single-variable anomaloscope matches during recovery from artificial red blindness. *J. Opt. Soc. Amer.*, 56:686–689, 1966.

An anomaloscope was designed so that full amounts of its red and green primaries could be adjusted to match yellow.

3. BARON, J., CABAU, A., & PARMENTIER-BELOUX, M. Application du test de Farnsworth 100 hue dans l'examen de la vision colorée. *Le Presse Med.*, 64:561–562, 1956.

The Farnsworth 100 Hue test was examined and compared with other tests. The authors concluded that the Farnsworth 100 Hue test was good for diagnosing the anomalies of color vision and also for diagnosing difficulties in color discrimination.

4. BELCHER, S. J., GREENSHIELDS, K. W., & WRIGHT, W. D. Color vision survey using the Ishihara, Dvorine, Boström, Boström-Kugelberg, and American-Optical Hardy-Rand-Rittler tests. *Brit. J. Ophthal.*, 42:355–359, 1958.

Five hundred subjects were tested with five different sets of pseudo-isochromatic plates. The tests were compared for division of subjects between normal and defective and for screening efficiency of each plate.

5. BOYNTON, R. M. & WAGNER, M. Two-color threshold as a test of color vision. *J. Opt. Soc. Amer.*, 51:429–440, 1961.

The two-color threshold is obtained by finding the just visible luminance of a test flash of one color seen against the background of another color. An examination of green-on-red thresholds plotted against red-on-green thresholds reveals a separation of normal subjects from the color defective. Within the color defective group, the test seems to provide a quantitative assessment of the degree of color defect.

6. BURNHAM, R. W. & CLARK, J. R. A color memory test. *J. Opt. Soc. Amer.*, 44:658–659, 1954.

A test for color memory has been developed using chips from the Farnsworth-Munsell hue series. The observer selects from a hue circle of color samples the one which most resembles a test sample presented a short time before. This procedure is repeated for a number of test samples.

7. CAMERON, R. G. Rational approach to color vision testing. *Aerospace Med.*, 38:51–59, 1967.

A rational approach to color vision testing demands the elucidation of three points: whether a color vision defect is actually present, what it is, and whether the defect is compatible with the requirements of the examining service. Testing of 5,141 pilot candidates indicates 5.17% defectives. This indicates that about 2½% of the defectives were self-eliminated, and the rejection of 3.9% of all candidates can be regarded as an average figure. The paper offers a plea for uniformity of definition, of methodology, and particularly of terminology.

8. CHAPANIS, A. A comparative study of five tests of color vision. *J. Opt. Soc. Amer.*, 38:626–649, 1948.

This study compares the American Optical Company, Ishihara, Meyrowitz, Boström, and Boström-Kugelberg color vision tests. The author reports that the Boström-Kugelberg test is the best all around test of color deficiency evaluated in the study. The Ishihara was next best. The author found the Bostrom and Meyrowitz plates to be unsatisfactory. The author reports that neither visual acuity nor age is related to performance on the tests used in this study.

9. CHAPANIS, A. Diagnosing types of color deficiency by means of pseudo-isochromatic tests. *J. Opt. Soc. Amer.*, 39:242–249, 1949.

Five pseudo-isochromatic tests of color vision (the American Optical Company, Ishihara, Meyrowitz, Boström, and Boström-Kugelberg) were evaluated for their ability to differentiate two kinds of color deficient individuals. The Bostrom plates were found to be worthless for this purpose, the Meyrowitz plates somewhat better, and the Ishihara plates best. None of the plates in the other two tests was found to be diagnostic.

10. COLE, B. L. Misuse of the Ishihara test for color blindness. *Brit. J. Physiol. Opt.*, 20:113–118, 1963.

This paper examined the weaknesses of the Ishihara test for color blindness and suggested two working rules for its use: (1) A patient who misreads three plates or less is almost certain to have normal color vision. If he misreads between three and six plates, he can be considered to be normal, provided some of the errors are not typical of the errors that the color defective makes. (2) No reliable quantitative assessment of the severity of the defect can be ex-

pected from the Ishihara test although between six and fifteen errors may indicate a mild defect.

11. Collins, W. E., Casola, A. S., & Zegers, R. T. The performance of color-blind subjects on the color aptitude test. *J. Gen. Psychol.*, 64:245–250, 1961.
The paper compared the performance of color deficient subjects on the Color Aptitude test with performance on the Hardy-Rand-Rittler plates. The results show that the color defectives had poor scores on all color series of the Color Aptitude test. There was some evidence that lower scores on the red series may indicate a protan-defect, while lower scores on the green series may indicate a deutan-defect.

12. Colombi, A., Vitali, G., & Carta, F. Impiego di una funzime discriminante nella valutazime della capacta diagnostica delle favole di Ishihara. *Annal. Ottal. Clin. Ocul.*, 91:954–961, 1965.
This paper described the use of a discriminative function in the evaluation of the diagnostic efficiency of the Ishihara plates.

13. Crawford, A. A description of an anomaloscope. *Brit. J. Physiol. Opt.*, 8:173–175, 1951.
This paper described a simple filter anomaloscope.

14. Crawford, A. The Dvorine pseudo-isochromatic plates. *Brit. J. Psychol.*, 46:139–143, 1955.
This is a review of the second edition of the Dvorine pseudo-isochromatic test. The reviewer concluded that the test is an effective screening test for separating color defectives from color normals.

15. Crone, R. A. Clinical study of color vision. *Brit. J. Ophthal.*, 39:170–173, 1955.
This paper described a modification of the Nagel anomaloscope, which permitted determination of (1) relative luminous efficiency of spectral light, (2) thresholds of wavelength discrimination in the spectrum, (3) thresholds of saturation discrimination in the spectrum, and (4) trichromatic coefficients of spectral colors.

16. Crone, R. A. Quantitative diagnosis of defective color vision: A comparative evaluation of the Ishihara test, the Farnsworth dichotomous test, and the Hardy-Rand-Rittler polychromatic plates. *Amer. J. Ophthal.*, 51:298–305, 1961.
The paper compared the pseudo-isochromatic plates of Ishihara with the Hardy-Rand-Rittler plates and the Farnsworth Dichotomous test. The threshold of wavelength discrimination at 590nm was taken as a measuring rule. The Ishihara plates proved excellent for differentiation between normals and abnormals but were unsuitable for quantitative differentiation. The H-R-R plates, on the contrary, were unsuitable for differentiating between normals and abnormals, but were very good for quantitative differentiation. For the latter, the Farnsworth Dichotomous test was also usable though to a lesser degree.

17. Dimmick, R. L. & Wienke, R. E. How red is red? *Amer. J. Psychol.*, 71:298–304, 1958.
Selected portions of the red end of the spectrum were evaluated. The results indicated that the use of different primaries in anomaloscopes will result in slightly different red-green ratios. The results indicated that the red-green ratio is a function of the luminance level of the yellow comparison stimulus. The authors suggested that more rigorous results may be obtained in anomaloscopic examinations if the yellow comparison stimulus is at a fixed luminance level.

18. Dvorine, I. Quantitative classification of the color blind. *J. Gen. Psychol.*, 68:255–265, 1963.
A comparative study of 34 color vision defectives disclosed that 19 of them were diagnosed alike with the Dvorine, H-R-R, and Tokyo Medical College tests; the Dvorine and TMC tests were in agreement quantitatively in 27 of 34 cases; the Dvorine and the H-R-R were in agreement quantitatively in 25 of 34 patients; and the H-R-R and TMC were in agreement quantitatively in 20 of 34 cases presented. The author concluded that failure to pass a color vision test which is based on progressive increase of chroma in polychromatic plates (H-R-R and TMC) would seem less effective an indicator of the extent of color vision defect than the estimation of the deficiency from the number of missed plates or errors on the Dvorine test.

19. Dvorine, I. The importance of color vision in the military services. *Optom. Wkly.*, 54:1191–1195, 1963.
The author described the various types of color vision tests in use. He recommended the pseudo-isochromatic test above all other types, but suggested that the armed services must have their own set of plates designed for their exclusive use.

20. Farnsworth, D. The Farnsworth-Munsell 100 hue and dichotomous tests for color vision. *J. Opt. Soc. Amer.*, 33:568–578, 1943.
This paper described the construction and use of the Farnsworth-Munsell 100 Hue test and the Farnsworth Dichotomous test for color vision.

21. Farnsworth, D. Testing for color deficiency in industry. *A.M.A. Archs. Ind. Hlth.*, 16:100–103, 1957.
A four-part classification of color vision was suggested based upon whether applicants pass or fail pseudo-isochromatic plates, the Farnsworth Lantern, or the Farnsworth D–15 Dichotomous test. An applicant who passed all three tests was described as normal. An applicant who passed the lantern and the Dichotomous test but failed the plates was classified as a mild defective. An applicant who passed the Dichotomous test but failed the plates and the lantern was described as moderate defective. An applicant who failed all three tests was classified as a severe defective.

22. Farnsworth, D. & Foreman, P. Development and trial of the New London Navy lantern as a selection test for serviceable color vision. BuMed Project X–457 (AV–241–K), Color Vision Rpt. No. 12, 6 May 1946. U.S. Submarine Base, New London, Connecticut.
A color vision testing lantern was designed which was intended to be as quick and convenient to give as pseudo-isochromatic plates or other standard

tests, which would be more reliable in its pass-fail criteria and less dependent upon the training and personal interpretation of the examiner. A model of the proposed Navy Lantern, called the New London Prototype Model, was tested on over 2,000 individuals and compared with other standard tests for color vision.

23. FLEKKEL, A. B. Differential diagnosis of color vision. (in Russian) *Dokl. Akad. Nauk. SSSR.*, 100:57–60, 1955.

This paper compared the performance of color defectives on the Rabkin plates and on the Rautian anomaloscope in distinguishing color signal lights. The paper concluded that Rayleigh equations are an inadequate index of color defect.

24. FLEKKEL, A. B. An experiment in the application of Yustova's tables for investigation of color vision. (in Russian) *Biofizika*, 1:708–712, 1956.

This paper described the Yustova plates for color vision testing and their use.

25. FREY, R. G. Welche pseudoisochromatischen Tafeln sind für die Praxis am besten geeignet? *Albrecht v. Graefes Arch. Ophthal.*, 160:301–320, 1958.

This paper compared the Boström, Boström-Kugelberg, H-R-R, Ishihara, Rabkin, and Stilling color plate tests.

26. FREY, R. G. Zur Vereinfachung der Farbensinnprüfung. *Wien. Klin. Wschr.*, 73:852–854, 1961.

In order to reduce the time spent in testing color vision and, at the same time, to make reliable tests, it is necessary to combine pseudo-isochromatic plates with high selectivity and usefulness. The author recommended use of the following four plates: Farnsworth's tritan plate, Boström's plate 10, Bostrom-Kugelberg's plate R, and Rabkin's plate 14.

27. FREY, R. G. Die Trennschärfe einiger pseudoisochromatischer Tafelproben. *Albrecht v. Graefes Arch. Ophthal.*, 165:20–30, 1962.

This paper compared the pseudoisochromatic plate tests of Dvorine, Velhagen, and Polack. The author recommended the Dvorine without changes. He concluded that the Velhagen test becomes more useful when restricted to the 17 plates of raised selectivity. He concluded that a selection of only 14 plates from the Polack test is useful.

28. FREY, R. G. Zur Differentialdiagnose der angeborenen Farbensinnstörungen mit pseudoisochromatischen Tafeln. *Ophthalmologica (Basel)*, 145:34–48, 1963.

A collection of pseudo-isochromatic plates was examined to determine their differential diagnostic possibilities and the results were compared with anomaloscope findings. It was possible to a certain extent to determine whether a protan or deutan disturbance existed. The Rabkin tables produced a correct qualitative diagnosis in 97.4% of the cases, Dvorine in 94%, Hardy-Rand-Rittler in 90.1%, Polack in 88%, Ishihara in 82.7% and the Tokyo Medical College color vision test in 65.2%. The quantitative diagnosis in all cases varied considerably from the findings of the anomaloscope. More particularly those cases which would be classified as "mild" by the Hardy-Rand-Rittler tables or by the Tokyo Medical College test should probably be classified as anomalous trichromats. From examinations made with the TMC no certain conclusions can be drawn as to the nature and extent of the color disturbance.

29. FREY, R. G. Zur Wahl der geeigneten Beleuchtung für die Farbensinnprufung mit pseudoisochromatischen Tafeln. *Wien. Klin. Wschr.*, 76:170–172, 1964.

This paper enumerated the illumination and color temperature of the illuminants required by various pseudo-isochromatic plates. The author emphasized the need for holding illumination constant in the testing of subjects.

30. FREY, R. G. Erfahrungen mit der 7. Auflage der polychromatischen Tafeln J. B. Rabkins. (Experiences with the seventh edition of the J. B. Rabkin polychromatic tables). *Klin. Mbl. Augenheilk*, 145:97–106, 1964.

The seventh edition of the "Polychromatic charts" of Rabkin were used to test two groups of 170 persons each, who had been examined with the anomaloscope and classified accordingly into one group with normal color sense and another with defective color sense. In an abridged form, this collection can be recommended for the rapid and reliable detection of persons with defective color vision. A positive differential diagnosis cannot be established by means of these charts. The charts for the examination of the color vision of children, charts which were enclosed for the first time in this edition, need to be improved.

31. GALLAGHER, J. R. & GALLAGHER, C. D. Color vision screening of preschool and first grade children. *Arch. Ophthal.*, 72:200–211, 1964.

Observations relevant to the color vision testing of preschool and first grade children were reported. About 3% of each of the two groups studied appeared to have a color vision defect of sufficient degree to constitute a practical handicap in correctly discriminating colors. A simple screening method for detecting significant degrees of color vision deficiency in preschool and first grade children was described. It is based on a selected number of AO H-R-R plates.

32. GOLDSTEIN, A. G. & BROOKS, R. A red-green color vision test employing transparencies. *Percept. Motor Skills*, 11:229–230, 1960.

A red-green color vision test employing transparencies was described and data for 18 subjects were presented. The authors recommended continuing research to determine whether correctly exposed transparencies may be employed for group color vision testing.

33. HAEFNER, R. A decade of research in color blindness. *Psychol. Newsltr., N.Y.U.*, 8:128–148, 1957.

This is a survey article reviewing the literature on color defects from 1946 to 1955, inclusive. All aspects of color defect, including color testing, were reviewed.

34. HARDY, L. H., RAND, R., & RITTLER, M. C. Test for the detection and analysis of color blindness. III. Rabkin test. *J. Opt. Soc. Amer.*, 35:481–491, 1945.

From an examination of the second edition of the Rabkin test the authors concluded that, properly administered, the test affords a good device for screening the color defective from the color normal if 75 is taken as the critical performance score. The test taken as a whole affords an excellent means of classifying red-green dichromats into the two groups: protanopic and deuteranopic; it also provides for classification of red-green anomalous trichromats into two groups: deuteranomalous and protanomalous. The test is not adequate to differentiate between anomalous trichromasy and dichromasy.

35. HARDY, L. H., RAND, G., & RITTLER, M. C. The H-R-R polychromatic plates. I. A test for the detection, classification, and estimation of the degree of defective color vision. *A.M.A. Arch. Ophthal.*, 51:216–228, 1954.

The paper described the construction, administration, validation, and reliability of the H-R-R polychromatic plates.

36. HARDY, L. H., RAND, G., & RITTLER, M. C. The H-R-R polychromatic plates. II. Comparison of qualitative and quantitative classifications by H-R-R plates and other tests. *A.M.A. Arch. Ophthal.*, 52:353–368, 1954.

This paper presented further validation and reliability information concerning the H-R-R polychromatic plates. It presented a comparison of the qualitative and quantitative diagnoses yielded by the H-R-R plates with performances on other tests of color vision.

37. HARDY, L. H., RAND, G., & RITTLER, M. C. H-R-R polychromatic plates. *J. Opt. Soc. Amer.*, 44:509–523, 1954.

This paper presented approximately the same information as the two previous papers.

38. HIOKI, R. & NAKAMURA, Y. Hioki's polarization anomaloscope. *Amer. J. Ophthal.*, 40:559–562, 1955.

This paper described construction of a polarization version of the Nagel anomaloscope.

39. HOMBERG, L. The distribution and reliability of certain color vision data as measured by the Pickford-Nicolson anomaloscope. *Psychol. Res. Bull.*, 3:7pp., 1963.

This paper presented the standardization data for the Pickford-Nicolson anomaloscope. The instrument was found to be a valuable and sensitive tool for color vision testing as well as for psychophysical investigation.

40. HOOGERHEIDE, J. Considerations about the acceptability of mild color defective trichromats in flying personnel. *Aeromed. Acta*, 7:17–23, 1959, 1960.

The author recommended testing flying personnel with the Hardy-Rand-Rittler plates. He also recommended passing those people who make no mistakes in the medium and strong plates. The author suggested that pilots with mildly anomalous color vision do not pose any danger.

41. JOSHI, V. G. Brightness contrast as a source of error in the Ishihara test for color blindness. *Brit. J. Physiol. Opt.*, 18:239–242, 1961.

Plates of the Ishihara test for color blindness were photographed in black and white by so modifying the technique of exposure that the color sensitivity of the film emulsion was made uniformly constant to all spectral colors. The older the edition, the greater the visibility of the numerals in the photographs. Factors of "color contrast" and "brightness contrast" appeared to be of comparative importance in the Ishihara test.

42. KATAVISTO, M. Pseudo-isochromatic plates and artificial light. *Acta Ophthal. (Kobenhavn)*, 39:377–390, 1961.

Thirty persons with normal color vision and 50 with defective color vision were tested with Boström II, Ishihara, and Stilling pseudo-isochromatic plates in daylight, and by the light of tungsten lamps and flourescent tubes with high color temperature. Similar results were obtained with the Boström plates with each of these three sources of light, and with the Ishihara plates in daylight and in the light of flourescent tubes. The results obtained with Stilling plates were reliable only in daylight. Thus, the Bostrom and Ishihara plates are well suited for tests of color vision by light of flourescent tubes, which can be recommended as a standard illuminant during the dark winter months.

43. KATAVISTO, M. Väärlaistin tutkimisesta pseudo-isokromaattisilla tauluilla. (Color sensitivity examination with pseudo-isochromatic tables). (in Finnish) *Suom. Lääklehti*, 17:121–126, 1962.

The principles for use of pseudo-isochromatic tables and the reliability of obtained results were surveyed by making comparisons between the Stilling, Boström (IIB), Ishihara, and Tokyo Medical College tests. The latter was recommended as a rapid screening test for mass examinations of color vision. The importance of an accurate sense of color in certain professions was stressed and, hence, it was proposed that the testing of color vision be included in vocational guidance.

44. KIRSCHEN, M. The color rator: a new instrument for the assessment of color aptitude in industry. *Amer. J. Optom.*, 36:137–143, 1959.

An instrument was described for the determination of color aptitude or color discrimination with the red and green portions of the spectrum. The matching principle was used. An additional advantage of this instrument was that the procedure as outlined was sufficiently simple for its administration by a lay person at the employment level of industry. Criteria for its use were proposed from a preliminary study of 21 subjects. Range of settings at various wavelengths was adopted as principle criterion for pass or fail decisions.

45. LAKOWSKI, R. Testing of colour vision in prospective printers' apprentices and the problems this presents in selection. *Brit. J. Physiol. Opt.*, 22:10–32, 1965.

The performance of the printers' apprentices (boys between the ages 14–17) on all the color vision tests used in this study was different from that of the control group. This difference appeared as differences in the most frequent type of response accepted by the members of each of the two populations, and as differences in the variability of such performances. This was best seen in the anomaloscope, where there was a difference in terms of mid-matching points accepted by the two groups and this applied also to variability of their matching ranges. There was a decidedly higher incidence of subjects with minor color deficiencies in the experimental group. There were twice as many deuteranopes as found in other studies. The author suggested that perhaps ages 14 through 16 are the best times to test color vision for vocational purposes, for at this stage any latent weakness will be indicated.

46. LINKSZ, A. The Farnsworth panel D–15 test. *Amer. J. Ophthal.*, 62:27–37, 1966.
This paper discussed the principles and uses of the Farnsworth panel D–15 test. Extending its use for diagnosing tetartan and achromatic defects was also discussed.

47. MAJIMA, A., AWAYA, S., & TANABE, S. Evaluation on Ishihara plates (numeral and winding-line plates), H-R-R plates, and T.M.C. plates for screening tests. (in Japanese) *Jap J. Clin. Ophthal.*, 18:493–496, 1964.
The authors reported that the Ishihara is an excellent test for screening, while the H-R-R plates proved unsatisfactory for this purpose.

48. MCCULLOCH, C., TURNOUR, N. C., & SMILEY, J. R. A field study of Hardy-Rand-Rittler color vision plate test. *Amer. J. Ophthal.*, 48:124–129, 1959.
This paper compared the H-R-R color vision test with the American Optical Company pseudo-isochromatic plate test used by the RCAF and with the RCAF lantern. The authors suggested that with the Hardy-Rand-Rittler test a simplified form can be used and subjects may record their own responses.

49. MUNTEANU, M. Examination of the colour sense in the navy. The chromatoscope. *Rev. Int. Serv. Santé. Armées.*, 38:361–363, 1965.
This paper described a form of color lantern and its use in the testing of color vision.

50. NAKAJIMA, A., ICHIKAWA, H., NAKAGAWA, O., MAJIMA, A., & WATANABE, M. Ishihara test in color vision defects. Studies on a statistical method for evaluation of the screening efficiency of several plates. *Amer. J. Ophthal.*, 49:921–929, 1960.
A set of Ishihara test plates (25 plates from the thirteenth edition) was used for the screening of color vision defects in 3,033 school children aged six to ten years, along with three other plates for tritanopes and anomaloscopic examination for defectives picked up by the screening. Using the number of misread plates as criterion, this set of Ishihara test plates could separate red-green defectives very clearly from normals. Analysis of the distribution of misreadings by statistical methods was presented. The Poisson law can be used for the approximation of the observed distribution, and efficiency in error of screening can be estimated on this basis.

51. PÉCHOUX, R., RESSÉGUIER, J., DEFAYOLLE, M., & RAYMOND, R. Étude d'une batterie d'épreuves pour la détection des anomalies de la vision des couleurs dans les centres de seléction. *Bull. Cent. Étude Rech. Psychotech.*, 6:171–182, 1957.
This paper compared Beyne's lantern with the orthorater and the Ishihara test. The author recommended that all subjects be examined with the orthorater. Those who obtain scores of eight or more on the scale of ten should be considered normal. Those who score seven or less should undergo the simplified Ishihara test. Those who score exactly eight in the Ishihara test should be considered normal. Those whose score on the Ishihara is less than or equal to seven should be examined by Beyne's lantern.

52. PERDRIEL, G. L'examen de la vision des couleurs en pratique courante. *Annee Ther. Clin. Ophthal.*, 11:221–237, 1960.
This article surveyed existing color vision tests. It has brief descriptions of the tests but no comparisons were made among them.

53. PERDRIEL, G. Le test de Farnsworth 100 hue. *Ann. Oculist. (Paris)*, 195:120–130, 1962.
This paper described the principles and uses of the Farnsworth 100 Hue test.

54. PETERS, G. The new Dvorine color perception test. *Optom. Wkly.*, 45:1801–1803, 1954.
This paper presented some normative data for the second edition of the Dvorine color perception test.

55. PETERS, G. Diagnostic sensitivity of color perception tests. *Optom. Wkly.*, 46:136–137, 1955.
This paper compared the second edition of the Dvorine color perception test with the American Optical Company color perception test. The author concluded that the second edition of the Dvorine test was a more sensitive diagnostic instrument for the detection of color defects than was the American Optical Company color test (18 plate selection).

56. PETERS, G. A color-blindness test for use in vocational guidance. *Optom. Wkly.*, 48:1171–1173, 1957.
A quantitative classification table was presented as an aid in the interpretation of the Dvorine color perception test. This provides a classification as to degree of defect, the percentages of color blindness that may be found in the general population for each degree of defect, and an estimate of the vocational limitation resulting from such defects.

57. PICKFORD, R. W. Test for color blindness. *Brit. Med. Bull.*, 9:82, 1953.
This is a review of the tenth edition of the Ishihara test. The author suggested that the tenth edition was less reliable than the eighth, and that the ninth edition fell between them.

58. PICKFORD, R. W. A practical anomaloscope for testing color vision and color blindness. *Brit. J. Physiol. Opt.*, 14:2–26, 1957.
A simple filter anomaloscope for testing red-green

and yellow-blue color vision was described. The technique for using the anomaloscope and norms for normal color vision and for color defective vision were provided.

59. PICKFORD, R. W. & LAKOWSKI, R. The Pickford-Nicolson anomaloscope for testing and measuring colour sensitivity and colour blindness, and other tests and experiments. *Brit. J. Physiol. Opt.*, 17:131–150, 1960.

An anomaloscope based on a simple colorimeter was described that permits red-green and blue-yellow tests.

60. RAND, G. & RITTLER, M. C. An evaluation of the AO H-R-R pseudo-isochromatic plates. A test for detecting, classifying, and estimating the degree of defective color vision. *A.M.A. Arch. Ophthal.*, 56:736–742, 1956.

The paper evaluated the AO H-R-R pseudo-isochromatic plates and compared them with the prototype H-R-R tests.

61. RAUTIAN, G. N. A new anomaloscope. (in Russian) *Biofizika*, 2:734–742, 1957.

This paper described an anomaloscope that permits three tests of color discrimination in addition to the usual Rayleigh anomaloscope test.

62. RIU, R. Le problème de la perception des signaux colorés et du Daltonisme dans la marine. *Rev. Med. Nav.*, 11:7–35, 1956.

This paper presented the design for the Beyne chromoptemetric lantern. This lantern was designed to present lights equivalent to the color signal lights used in aviation, in the navy, or on railroads. Stimuli are variable in brightness, size, and duration. The lantern was compared with the lantern currently in use in the French Navy.

63. ROTH, A. Le test 28 hue selon Farnsworth. *Bull. Soc. Ophthal. Fr.*, 66:231–238, 1966.

This paper described a test using 28 hues taken from the Farnsworth-Munsell 100 Hue test and presented together as in the Farnsworth Dichotomous (Panel D–15) test. It was claimed that the test can isolate protans, deutans, tritans, tetartans, and achromats with scotopic vision.

64. SAWA, J. Note on the color vision tests with pseudo-isochromatic test plates. (in Japanese) *Jap. J. Clin. Ophthal.*, 18:1207–1211, 1964.

This paper described several pseudo-isochromatic test plates and assessed their individual characteristics. The author concluded that the Ishihara was the most reliable for screening subjects. He reported that other charts, especially the H-R-R and the TMC, gave equivocal results in borderline cases. For classifying color deficient subjects, the author found the H-R-R charts superior to the TMC charts. He found none of the available charts satisfactory for the determination of the severity of the color deficiency.

65. SCHMIDT, I. Comparative evaluation of the New London Navy lantern for testing color perception. Project No. 21–29–009. August, 1951. USAF Sch. Aviat. Med., Randolph Field, Texas.

The New London Navy lantern test for color perception was evaluated. The author recommended that subjects be adapted to room illumination for one-half hour before testing and that the number of retests in any one series be fixed.

66. SCHMIDT, I. Some problems related to testing color vision with the Nagel anomaloscope. *J. Opt. Soc. Amer.*, 45:514–522, 1955.

Topics dealt with include: elimination of training effects and determination of the total number of readings required to detect minimum practical differences between individuals; application and frequency distribution of the anomalous quotient; determination of the normal matching range of mixtures and of comparison yellow; and test-retest reliability of the Nagel anomaloscope.

67. SEEFELT, E. R. An evaluation of the validity and reliability of the AOC 15-plate pseudo-isochromatic test in routine testing. *Amer. J. Optom.*, 41:371–381, 1964.

This paper compared the classification of 409 airmen by the AOC 15-plate test with the classification determined by the anomaloscope. The author concluded that the AOC 15-plate test lacked the necessary validity and reliability to make it possible to obtain proper color vision classification by a single administration of the test under mass testing conditions.

68. SEEFELT, E. R. A comparison of the AOC and the Dvorine pseudo-isochromatic tests in color vision testing. *Amer. J. Optom.*, 42:250–255, 1965.

Color vision classifications of 210 airmen were determined by the AOC and the Dvorine tests as well as by the anomaloscope. Test results indicated the Dvorine test was a superior dichotomous test when compared to the AOC test. The contention that the Dvorine test might be used quantitatively did not seem to be supported by the data.

69. SEKI, R., OHTA, Y., TAJIRI, K., KUBATA, K., & FUKUDA, T. The results on color vision tests by the panel D–15. (in Japanese) *Acta Soc. Ophthal. Jap.*, 68:1312–1323, 1964.

This paper reported the study of color vision testing using the panel D–15 on normal subjects, congenital and acquired color deficient subjects. Many congenital deuteranomalous and protanomalous subjects passed the test with no errors. Many acquired color deficient subjects were classified tritan.

70. SLOAN, L. L. Evaluation of the Tokyo Medical College color vision test. *Amer. J. Ophthal.*, 52:650–659, 1961.

The Tokyo Medical College color vision test was described and evaluated by comparisons with the Ishihara test, twelfth edition, and a special group of 16 plates. The TMC test agreed, with one exception, with a classification determined by the 31 plates of the two other tests.

71. SLOAN, L. L. & HABEL, A. Tests for color deficiency based on the pseudo-isochromatic principle. A comparative study of several new tests. *A.M.A. Arch. Ophthal.*, 55:229–239, 1956.

This paper compared the Ishihara, Dvorine, and AO H-R-R tests. All tests detected the great ma-

jority of those with deficient color perception for red and green. Each of these tests, however, occasionally failed to detect mild degrees of red-green deficiency. Misclassification of normal subjects as color deficient was more likely to occur with the AO H-R-R screening plates than with either the Ishihara or the Dvorine screening tests.

72. STAMS, A. Controversial results in examinations of the colour sense by employment of customary methods. *Klin. Mbl. Augenheilk*, 147:261–264, 1965.
When color testing was done with the Stilling-Velhagen tables, the florcontrast and the anomaloscope controversial results were obtained. Relevant factors were mentioned.

73. TOPLEY, H. Sight testing for the merchant navy. *Brit. J. Physiol. Opt.*, 16:36–46, 1959.
This paper described a lantern test for color vision and its use in the screening of applicants for seaman.

74. TSUTSUMI, S. A new color vision test. (in Japanese) *J. Clin. Ophthal.*, 18:605–610, 1964.
An attempt was made to convert normal color vision into artificial color defective states corresponding to protanomaly, deuteranomaly, and tritanomaly by wearing cyan, magenta, or yellow filters respectively. The ability for color discrimination was tested under these states; it was found that the chromatic discrimination pattern for red-purple, purple, and blue-purple plates could serve as a guide in determining the kind and degree of color anomaly.

75. UMAZUNE, K., SEKI, R., and OBI, S. Trial manufacture of new colour vision test plates. Report 1. (in Japanese) *Acta Soc. Ophthal. Jap.*, 58:732–735, 1954.
This is a report of the test manufacture of the color plates for the Tokyo Medical College color test.

76. VICS, I. I. A clinical evaluation of color testing and color perception. *Amer. J. Optom.*, 43:582–592, 1966.
This paper discussed the use of several color tests for detecting color defects among school children.

77. WALLS, G. How good is the H-R-R test for color blindness? *Amer. J. Optom.*, 36:169–193, 1959.
This is a highly critical review of the AO H-R-R test. The author reported that as a normal-abnormal screening device, the test was perhaps as good as the Ishihara and the Dvorine. The author reported that the test made 18% incorrect red-green diagnoses. He concluded that the test is an adequate normal-abnormal screen; he recommended, for serious work, the construction of a simple and inexpensive anomaloscope.

78. WALRAVEN, P. L. & LEEBEEK, H. J. Recognition of color code by normals and by color defectives at several illumination levels. An evaluation study of the H-R-R plates. *Amer. J. Optom.*, 37:82–92, 1960.
This paper reported the number of errors in color code readings as a function of illumination for subjects grouped according to classification on the H-R-R color plates. For all groups, the number of mistakes decreased as illumination increased. At all illuminations there were more mistakes the more severe the defect according to the H-R-R plates, except at the two highest illuminations where the normals and those with mild defects made equal numbers of mistakes.

79. WALRAVEN, P. L., LEEBEEK, H. J. & BOUMAN, M. A. ISCC color aptitude test—The interpretation of some testing results. Report No. WW1956–10. Instituut voor Zintuigfysiologie—R.V.O.-T.N.O. August, 1956.
This paper compared the scores of forty-eight normals and fifty-three color deficient subjects on the Color Aptitude test. The results indicate many color defectives with scores as high as those obtained by normals. The authors, therefore, questioned the value of the CAT as a test for color discriminating ability.

80. WILLIS, M. P. & FARNSWORTH, D. Comparative evaluation of anomaloscopes. BuMed Project NM 003 041.2601. Med. Res. Lab. Rpt. No. 190, 18 August, 1952. U.S. Navy Submarine Base, New London, Connecticut.
This study examined six anomaloscopes. It attempted to discover whether one type of instrument was better than another, and to determine the relation of anomaloscope scores to scores from other color vision tests. A combination score was proposed which reduces range and deviation to one figure and which gives an estimate of degree of color deficiency. This scoring method can be used with a comparative scaling technique that can be applied to all anomaloscopes to give comparable scores.

81. WRIGHT, W. D. Diagnostic tests for color vision. *Ann. R. Coll. Surg.*, 20:177–191, 1957.
This is a survey of various tests for color vision. The author concluded that, except for the colorimeter, there was no single test capable of diagnosing all types of defects with certainty. The author suggested that an effective battery of tests should include one of the confusion chart tests, the Nagel anomaloscope, and the Farnsworth-Munsell 100 Hue test.

82. YAMAMOTO, T. A new qualitative test for color vision. (in Japanese) *J. Clin. Ophthal.*, 16:383–387, 1962.
This paper described a color test plate based on discrimination of chroma. It is used for the classification of protanopic and deuteranopic color defective vision and for quantitatively classifying these defects.

83. YOSHIHARA, M. Study of objective measurement of color vision (report #2). (in Japanese) *Folia Ophthal. Jap.*, 13:598–610, 1962.
This paper reported measurement for color defect based on the optokinetic nystagmus produced by movement of a specially designed color tablet. Results indicated that the electro-nystagmograms of color-blind subjects were irregular in type and height of waves and in frequency and amplitude of oscillation. With this technique the author claimed success in screening and classifying the degrees of color blindness.

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