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A BRIEF GUIDE TO COLOR VISION TESTING FOR OPHTHALMOLOGY
RESIDENTS(U) SCHOOL OF AEROSPACE MEDICINE BROOKS AFB TX
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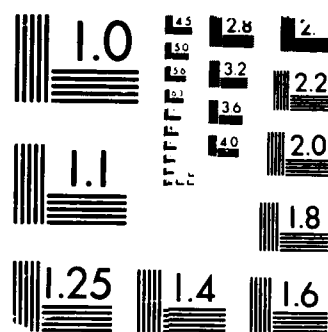
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USAF SCHOOL OF AEROSPACE MEDICINE
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Brooks Air Force Base, TX 78235-5301



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NOTICES

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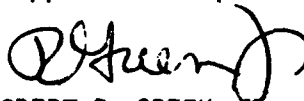
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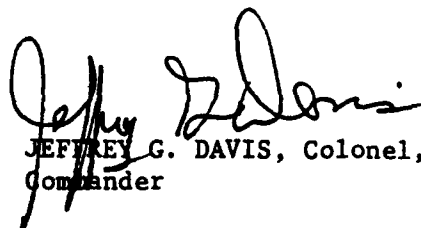
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A BRIEF GUIDE TO COLOR VISION TESTING FOR OPHTHALMOLOGY RESIDENTS

INTRODUCTION

The interpretation of color vision tests is straightforward. The real skill that must be developed is knowing what test or tests to perform. This paper will ~~teach you~~ how to perform and interpret the commonly used tests of color vision.

When faced with a possible color vision defect, the first question you should ask is: "Is this most likely a congenital anomaly or an acquired dyschromatopsia?" The second question to ask is: "How precisely do I need to define the defect?"

TESTING FOR ANOMALIES

Pseudo-Isochromatic Plates

These plates are an extremely useful rapid screening device for red-green defects, which for practical purposes constitute all of congenital color anomalies. Deutan or green-insensitive defects are present in every 1:16 males in the population (6%). Protan or red-insensitive defects are present in every 1:50 males (2%). These defects are X-linked. Thus, affected males pass to unaffected daughters, who in turn pass the defect to their sons. Females occasionally express the defect (at a rate of 1:200 or less; 0.5% of the population). Tritan (blue) defects are present in fewer than 1:100,000 of the population.

The pseudo-isochromatic plates contain cards with colored dots forming a figure against a multi-colored background (Fig.1). Individuals with normal color vision have little or no difficulty, distinguishing the figure from the background. Individuals with color defects, on the other hand, see only a random background.

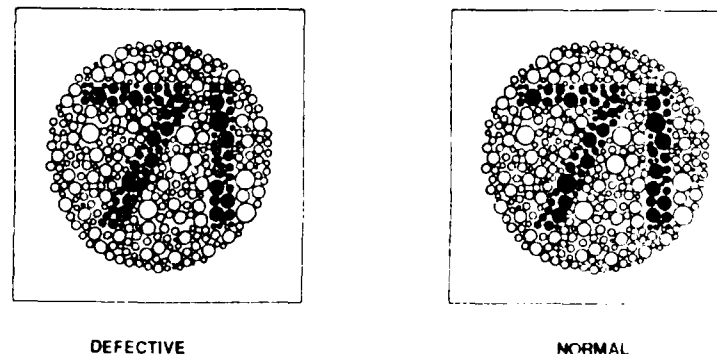


Figure 1. Pseudo-isochromatic plates.

The plates are inexpensive and easy to use. The Dvorine plates are most widely used in the United States; others are the American Optical, Ishihara, and the Tokyo Medical College plates.

Dvorine Plates

A full set of Dvorine plates includes 1 demo plate, 14 numerical test plates, and 8 pediatric/illiterate test plates. Twelve numerical plates (2-5 and 8-15) are nonspecific in that they indicate a defect is present, but not which type of defect it is. Two plates are specific, or "diagnostic" (6 and 7). If the subject doesn't see the number 9 on plate 6 or the number 2 on plate 7, the subject has a protan defect. If the subject doesn't see the number 5 on plate 6 or the number 6 on plate 7, the subject has a deutan defect. An easy way to remember this sequence is that the "protan" side of the plates has a reddish background, whereas the "deutan" side has a gray-green background. If the subject can't identify either number on plates 6 and 7, the subject may have a combined defect. Pediatric plates have lines for the pre-literate child to trace with a brush.

The plates don't quantify the amount of defect, but they are an excellent starting point for the evaluation of most congenital, as well as acquired, dyschromatopsias.

Before starting the test, place a patch over the left eye and tell the subject: "You will have 5 s to read each card. Colored numbers are printed on a colored background. If you can see the number, read it out loud." Present the plates for 5 s each at a distance of about 30 in. (76.2 cm) under the equivalent of natural daylight illumination. This test is best done with a Macbeth-Easel lamp (standard illuminant C) at a 45-degree angle to the plates. You may vary the plate sequence before testing the left eye.

Ten or more correct answers is normal; less than 10 correct answers is defective; 4-9 correct answers is a moderate defect; and 0-3 correct answers is a severe defect. Plate 1 is used to detect malingering. To read this plate, you need only 20/200 black and white vision.

While performing the test, avoid using color names. Be sure the subject is wearing the proper refraction (without tint in the spectacles or contacts).

Farnsworth D-15 Test

This test is an arrangement test which is good for detecting both red-green (deutan or protan) and blue-yellow (tritan) defects. Like the plates, this test is also quick and easy to use and, whenever possible, should be used with a MacBeth-Easel lamp. This test consists of a long box with 14 removable colored caps and 1 fixed reference cap. The subject is asked to arrange the caps in a sequence of equal hue steps. This procedure requires more concentration, patience, and manual dexterity than the pseudo-isochromatic plate test.

To administer the test, put the caps in a random order in the box's upper tray. Then, with the subject at a distance of about 20 in. (50.8 cm), patch

the left eye and instruct the subject to arrange them in order, according to color (hue), in the lower tray (Fig. 2); repeat with the right eye patched. There is no time limit. The scoring is performed by plotting the order directly onto a standard score sheet, simply drawing lines connecting the actual cap order. The diagnosis is made by comparing the axis of the cross-over pattern (Fig. 3) with the dotted lines on the score sheet.

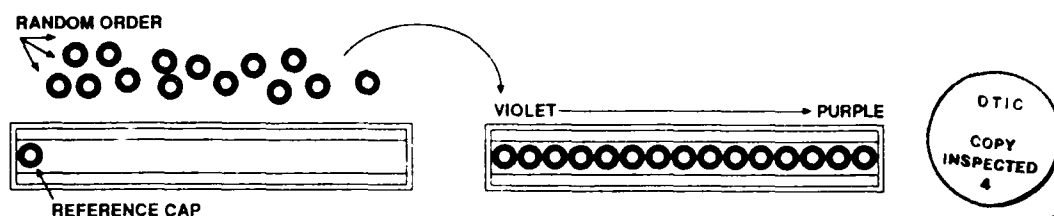


Figure 2. Farnsworth D-15 Test

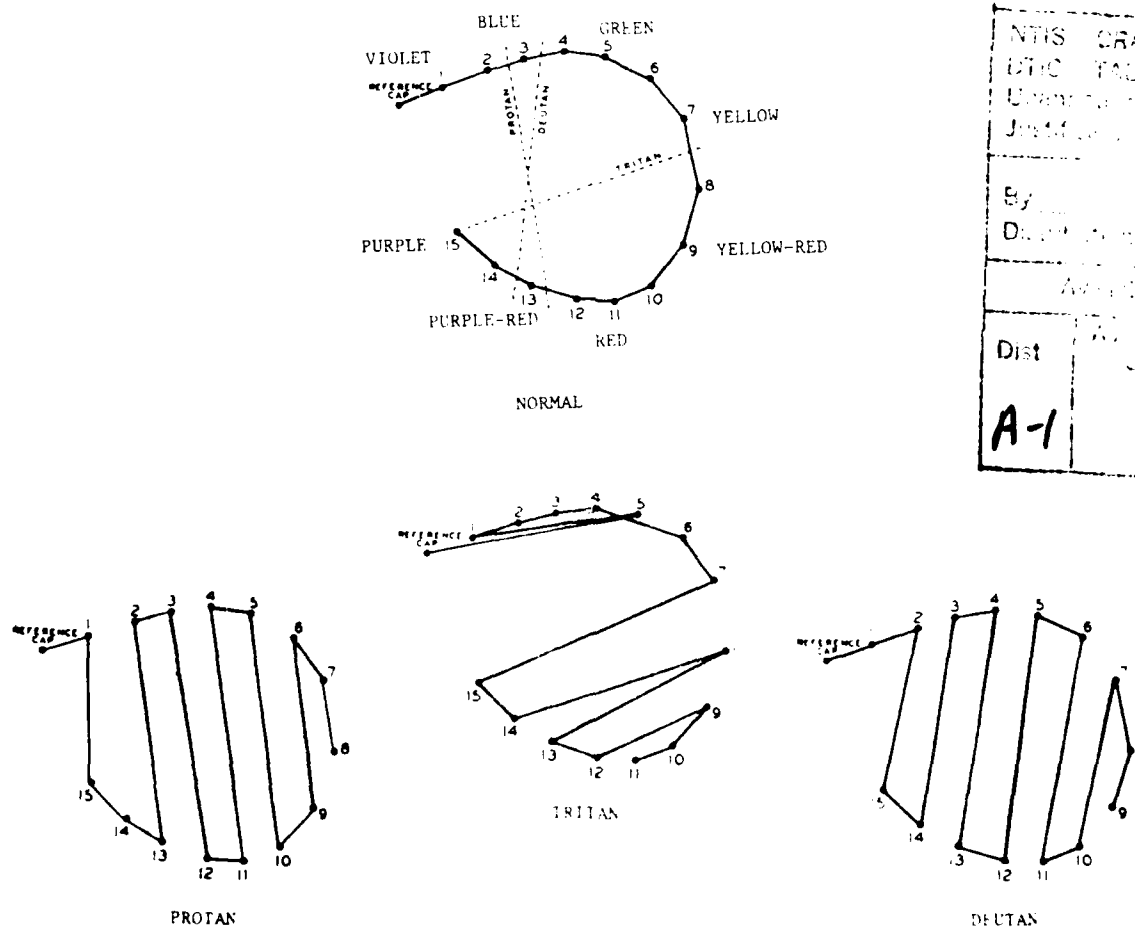


Figure 3. Farnsworth D-15 panel showing normal (above) and abnormal (below) patterns. Compare the axes of the dotted lines on the score sheet.

Anomaloscope

The anomaloscope is used for precisely discriminating deutan from protan defects. The anomaloscope also rapidly quantifies the degree of defect. The original anomaloscope was designed by Lord Rayleigh in 1881. He was the first to quantify the relationship between red, green, and yellow, which is now known as the "Rayleigh Equation:"

$$a\text{Red} + b\text{Green} = c\text{Yellow}$$

Where "a" and "b" stand for quantities of red and green and "c" stands for the luminance of yellow.

The instrument is delicate and looks something like a lensometer (Fig. 4), but has a viewing field composed of 2 adjacent semicircles. The upper half of the circle is filled with a mixture of spectral green (545 nm) and spectral red (670 nm). The lower half of the circle is filled with spectral yellow (589 nm) of variable luminance. White light is separated into the red, green, and yellow wavelengths by a prism mechanism.

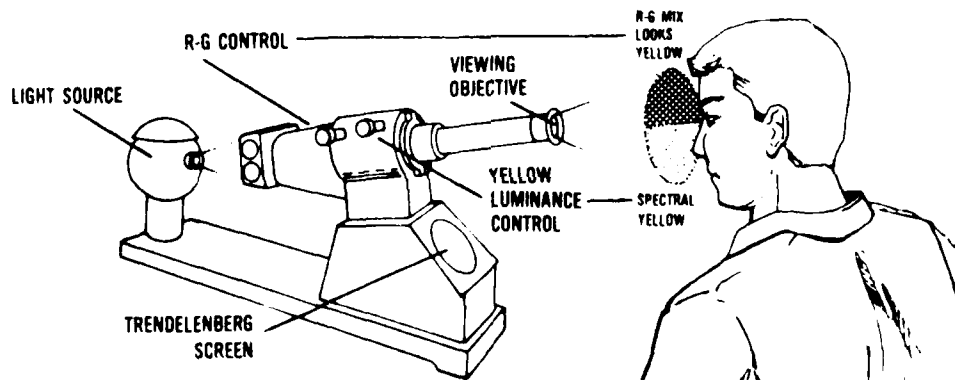


Figure 4. Anomaloscope: The patient turns the R-G control to make top semicircle appear yellow. Yellow luminance control is used to adjust to perfect match.

Two control knobs are provided: one allows for adjustment of the red (R) and green (G) mixture (scale 0 = green or short wavelength; scale 73 = red or long wavelength); the other knob controls yellow luminance. A normal match is a R-G scale setting of about 30 units. Normal yellow luminances are usually set at about 15 units.

Perform the test in a dark room with the R-G knob preset in the "normal" match range and the yellow luminance knob at 15. Have the subject preadapt to the Trendelenberg screen (white light) for 3 min. This adaptation period bleaches all the retinal pigments equally. If this adaptation isn't done, errors may result from unequal pigment bleaching. If, for example, the subject had been looking at a reddish background before the test began, the subject would have bleached more erythrolabe (red pigment) than chlorolabe (green pigment). This unequal pigment bleaching may result in an erroneous

protan type defect on the first trial of the test. To do the test, which has two parts, start with the right eye.

Part 1 (finding the average match): reset the R-G control anywhere away from a perfect yellow match and ask the subject to adjust both the R-G and Yellow controls until he obtains what he believes to be a match. Record the settings. Repeat this sequence for a total of five trials with each eye. Then, average the results.

Part 2 (finding the range): test the range of R-G matches that the subject finds acceptable. This range is usually within 5 scale units above and below the subject's average match determined in Part 1. To find the range, start by turning the R-G control 5 scale units either above or below the subject's average match. Move in one-unit steps toward the subject's average match asking, "Is this a match?" on each trial. Record the accepted range of matches.

Extreme anomalous trichromats and dichromats will have average matches far from 30 (normal), and very large R-G acceptance ranges. With these subjects, you will test the range by alternating the R-G control from extremes (0-73) in increments of 10 scale units toward the match until the range is determined.

If the average match is outside of the normal range toward red (toward scale 73), the subject is protan (Fig. 5). If the match is outside the normal range toward green (toward scale zero), the subject is deutan. If the match range is greater than ± 5 scale units, the subject is either an anomalous trichromat or a dichromat. Of course, dichromats will usually accept a greater range.

WHAT
THE SUBJECT
SEES

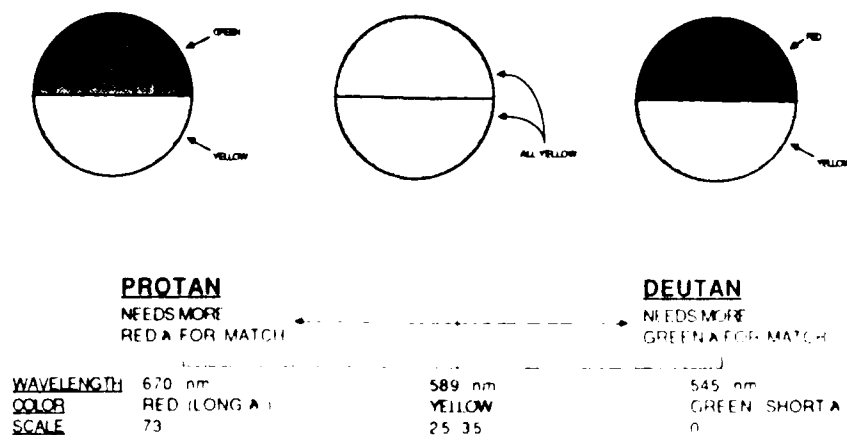


Figure 5. The relationship between defect, wavelength, and anomaloscope scale setting.

Farnsworth-Munsell 100-Hue Test

This test is the ultimate arrangement test, and is good for quantification of all types of color defects. Unfortunately, this test is time consuming (30-45 min), and like the D-15, requires patience, concentration, and manual dexterity. The test is an expanded version of the D-15, with 85 movable caps in 4 boxes. Two "pilot" colors are fixed at either end of each box (Fig. 6).

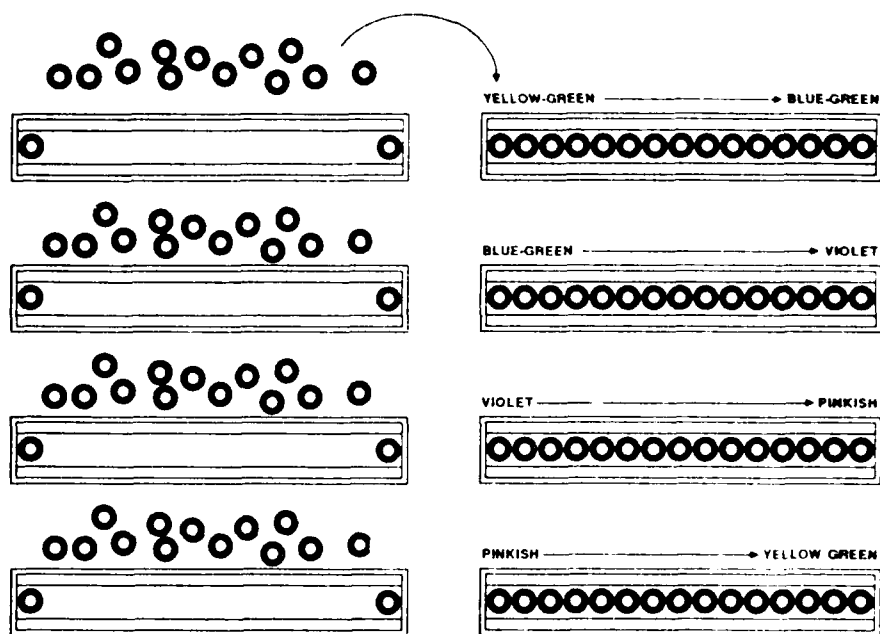
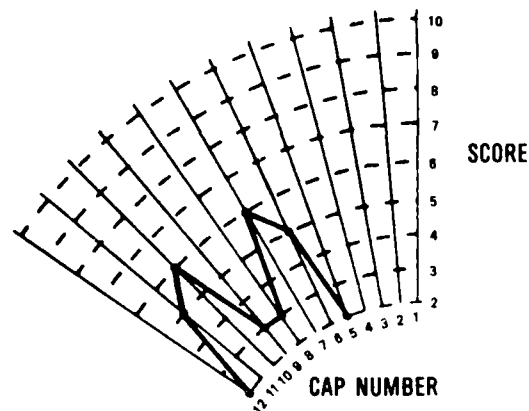


Figure 6. FM 100-HUE (test one box at a time).

As with the D-15 test, you must first randomly prearrange the caps. Test the right eye first. Have the subject arrange the caps in order, according to color (hue), in the box's lower tray. Be sure to use the MacBeth-Easel lamp.

The scoring system is fairly complex, but has been simplified by the availability of a computer tabulating program. If this computer program isn't available, you will have to score the test by the old method. First, calculate the score for each cap by taking the difference between its number and those of the 2 adjacent caps. Then add these scores and match the scores on a blank score sheet (Fig. 7).



Cap arrangement by subject	4	5	6	10	8	9	7	11	12	13
Differences	(1+1)	(1+4)	(1+4)	(4+2)	(2+1)	(1+2)	(2+4)	(4+1)	(1+1)	
Score		2	5	6	3	3	6	5	2	

Figure 7. Mapping on the FM 100-Hue scoresheet.

Mark the score on the appropriate radial line. A score of 2 (the lowest possible) is considered as zero. Finally, calculate the total score by adding the errors on each radial line, counting the inner circle as zero (caps actual score minus 2 equals the score used for adding totals).

Cap	5	6	7	8	9	10	11	12
Score	0 +	3 +	4 +	1 +	1 +	4 +	3 +	0
Total	= 16							

The type of color defect is identified by the pattern of bipolarity on the chart (Fig. 8). The axis of the chart error pattern is approximately 90 degrees to the type of defect the patient has. For example, the deuteranope of Fig. 8E has an axis approximately 90 degrees from the red-green areas of the central circle. Another way to classify the defect is to just look at the midpoint of the right-side error peak. Protans have midpoints between cap positions 62-70; deutans have midpoints between cap positions 56-61; and tritans have midpoints between cap positions 46-52.

A total score of 0-16 indicates superior discrimination, whereas a score greater than 100 indicates poor and probably abnormal discrimination.

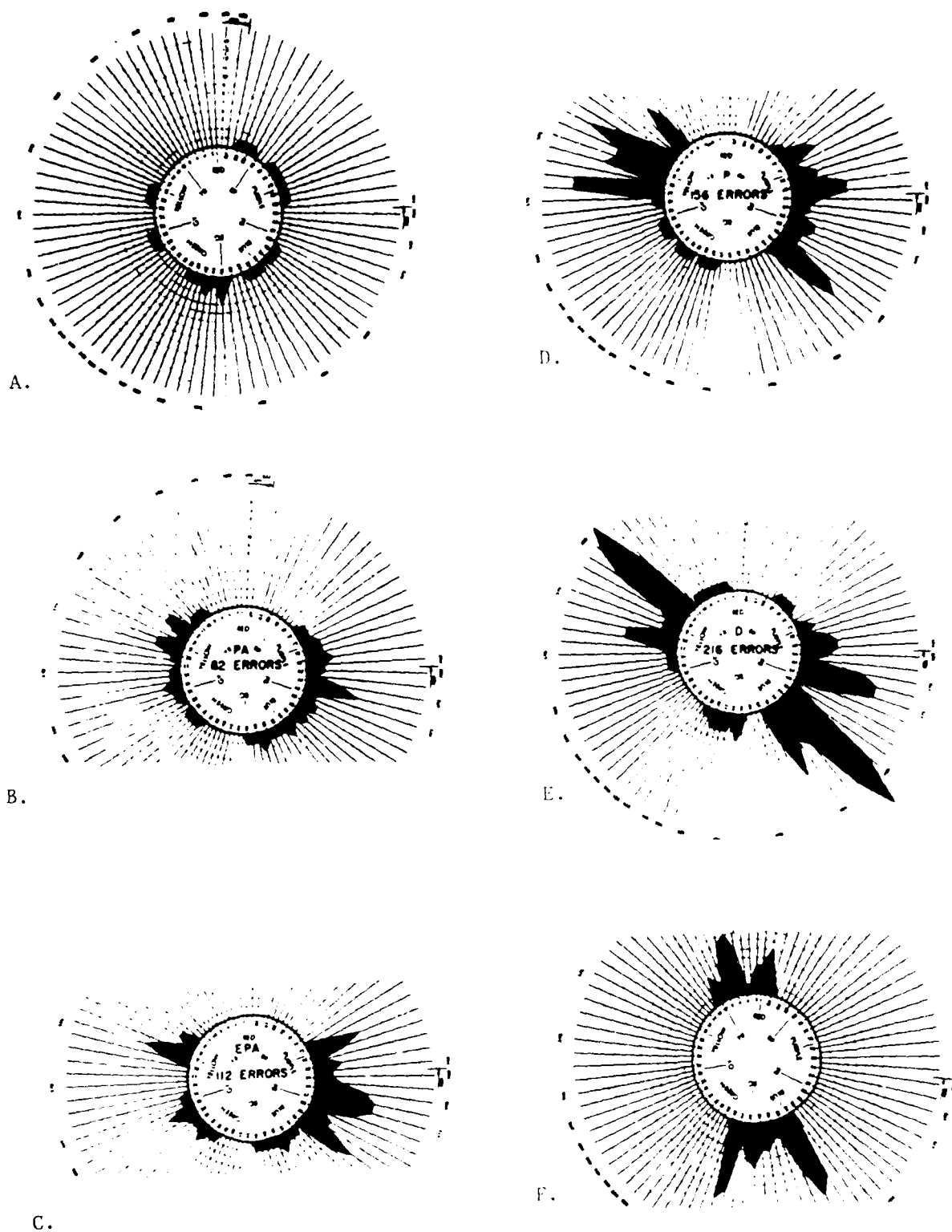


Figure 8. Examples of FM 100-Hue profiles: a) normal trichromat; b) protanomalous trichromat; c) extreme protanomalous trichromat; d) protanope; e) deuteranope; and f) tritanope.

HOW TO TEST FOR ACQUIRED DYSCHRMATOPSIAS

Acquired dyschromatopsias can mimic congenital defects, and it is helpful to know some simple, distinguishing characteristics. First, patients with acquired disorders are usually aware that there is something wrong with their color vision (and with their visual acuity or visual field) and will tell you. Second, acquired defects are usually unilateral or asymmetric. Third, they vary over time. This fact is useful for following progression and recovery of disease.

Retinal disorders, which may cause dyschromatopsia, include age-related macular degeneration (ARMD), diabetic retinopathy, central serous retinopathy, cystoid macular edema (CME), and chloroquine toxicity. Optic nerve problems may be due to a demyelinating neuropathy, nerve compression (e.g., Grave's or meningioma), anterior ischemic optic neuropathy (AION), or trauma. Demyelinating neuropathies often produce profound color defects with only mildly subnormal visual acuity. Chiasmal and occipital lobe lesions may also cause acquired dyschromatopsias, but are usually associated with vertical meridian field defects as well.

Colored Bottle Caps

These caps are a useful screening device for acquired defects. When hemianopia is suspected, have the patient fixate on your nose. Ask the patient where the color is "better" as you move the cap along the horizontal meridian from the "bad" to the "good" field. Do NOT hold the caps more than 10 degrees above or below the horizontal meridian; doing so could lead to confusion because the image will not fall on the fovea and, therefore, will miss the majority of color-sensitive cones even in normals. For altitudinal defects, move the cap up and down.

When looking for a demyelinating neuropathy or other optic neuropathy, present the red cap to the bad eye only and ask how "good" the color is, then uncover the good eye (the a-ha! response). Or, have the patient fixate on your nose and move the cap around your nose, asking if the cap "washes out" anywhere (relative paracentral scotomas). Severe ARMD will be associated with low-visual acuity and slowness on naming colors. On the other hand, a 20/200 cataract should not affect the ability to discriminate red, green, or blue caps if the macula is normal.

Pseudo-Isochromatic Plates Test

If the visual acuity is 20/200 or better, the patient should have no trouble reading the demonstration plate. Holding the plate near the face should allow patients with 20/400 vision to read it; failure to do this is diagnostic for malingering.

A relative hemianopia will cause a central dyschromatopsia and may be manifested as always missing the right or left digit of a pair. The patient with a large paracentral scotoma may have to search the plate before he is able to read it (watch eye movements).

FM 100-Hue Test

The real value of this test lies in its ability to rigorously quantitate the progression of a defect. Patterns produced by acquired defects will usually be diffuse as opposed to congenital bipolar patterns (Fig. 9). Unfortunately, this valuable test is not often used because of the time required to perform the test.

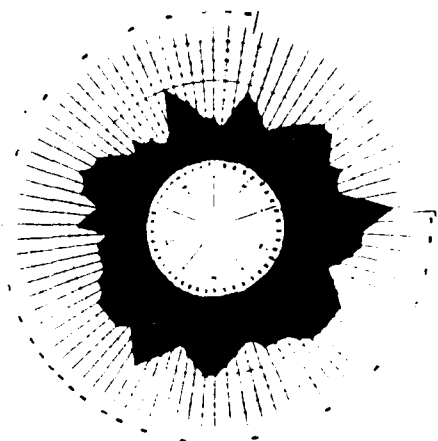


Figure 9. Acquired dyschromatopsia.

ANOMALOSCOPE

NAME: _____ TESTER: _____

LUMINANCE SETTING:

INITIAL IMPRESSION:

SUBJECT MATCH (5 trials): OD _____ m _____
OS _____ m _____

RANGE: OD _____
OS _____

DEFECT:	Deutan-defect	Mild	Mod	Severe
	Protan-defect			

Figure 10. Sample anomaloscope scoresheet.

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