TESTING COLOUR VISION

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THIS CHAPTER WILL INCLUDE A REVIEW OF:

- Book Tests
- Arrangement tests
- Nagel's anomaloscope

OVERVIEW OF COLOUR VISION TESTING

Q. Why are optometrists interested in testing colour vision?

- Occupational physical examinations
- Diagnose hereditary colour anomalies
- Diagnose and monitor diseases
- When testing colour vision, we usually want to know:
  - Is the patient's colour discrimination normal or abnormal?
  - What type of anomaly does the person have; that is, is the patient a protan, deutan, tritan or something else?
  - How severe is the colour anomaly? For example, is the person a dichromat or anomalous trichromat?
  - Is it an acquired or hereditary defect?

Different approaches to colour vision testing:

- Simple screening tests (red cap tests—See notes from the previous lecture.)
- Book tests: the HRR test and pseudoisochromatic plates (PIP)
- Arrangement tests
- Anomaloscopes
- Special occupational colour vision tests such as the Farnsworth Lantern (FALANT)

BOOK TESTS

PSEUDO-ISOCHROMATIC PLATES

Pseudo-isochromatic plates (PIP) are popular because they are easy to use and are relatively inexpensive. An example of a PIP test plate is shown in Schwartz, 2004 Fig. 6-11. The test uses a number of plates that consist of a coloured figure (such as a number) printed on a background of another colour or colours. A person with normal colour perception will be able see the figure, but the person with anomalous colour vision will not be able to discriminate the figure from the background, because the figure and background are made of colours that lie on a colour confusion line. This arrangement confuses a patient with a colour anomaly because it uses colours that appear to be isochromatic (same colour), but they really are not (pseudo-isochromatic).

Most PIP tests provide only a limited assessment of colour discrimination. They usually are simple pass/fail screeners for red-green anomalies only.

- They do not test for tritanopes
- If a patient fails, most tests do not differentiate between protans versus deutans
- They do not grade the degree of colour anomaly

One of the most well known PIP-type colour tests is the Ishihara test. Several versions of the Ishihara test have been published. Several other PIP-type colour vision tests are available. For more information, refer to Borish, 2006: Chapter 9, p. 316-318.

HRR TEST

The **HRR test** is one of the best colour vision tests available. It looks similar to the PIP tests, but is designed on a slightly different principle. Instead of using a coloured background, the HRR background is neutral gray. It uses the fact that dichromats or anomalous trichromats see colours as less saturated than normal. They therefore have difficulty discriminating certain colours from neutral gray; in particular, the colours that lie on the colour confusion line that goes through white.

Q. Can you name some advantages of the HRR test over most PIP tests?

A. Can differentially diagnose all three major types of anomalies (protan, deutan, tritan) and the degree of severity. It's fast and easy to use, especially with its organization of screening and diagnostic series.

ARRANGEMENT TESTS

In arrangement tests, the patient must sort coloured samples in a particular order. The two most well known arrangement tests are the **Farnsworth Munsell Hundred-Hue test** and the **D-15 test**, which comes in both a saturated and desaturated version.

FARNSWORTH MUNSELL HUNDRED-HUE TEST

This system tests the quality of a person's colour discrimination (superior, average, low) and can diagnose the general type of colour anomaly (protan, deutan, tritan) if it is present. It can also grade the severity of the defect numerically (Table 26.1). The test consists of 85 coloured caps, each with a different hue. The patient's task is to select the hue that looks most similar to a reference caps and place it next to the reference caps. He/she must then select, from among the remaining caps, the next hue in the colour sequence until all the caps have been arranged in continuous hue steps. The Hundred-Hue test is time consuming and expensive, so it is not commonly used in most optometry offices (Fig.26-1).

ARRANGEMENT TESTS

Table 26-1: *Interpretation of Hundred Hue test results*

COLOUR DISCRIMINATION SCORE	LOCATION OF BULGE CENTER
Superior: 0-16	Protan: 62-70
Normal/average: 20-100	Deutan: 56-61
Low discrimination: >100	Tritan: 46-52

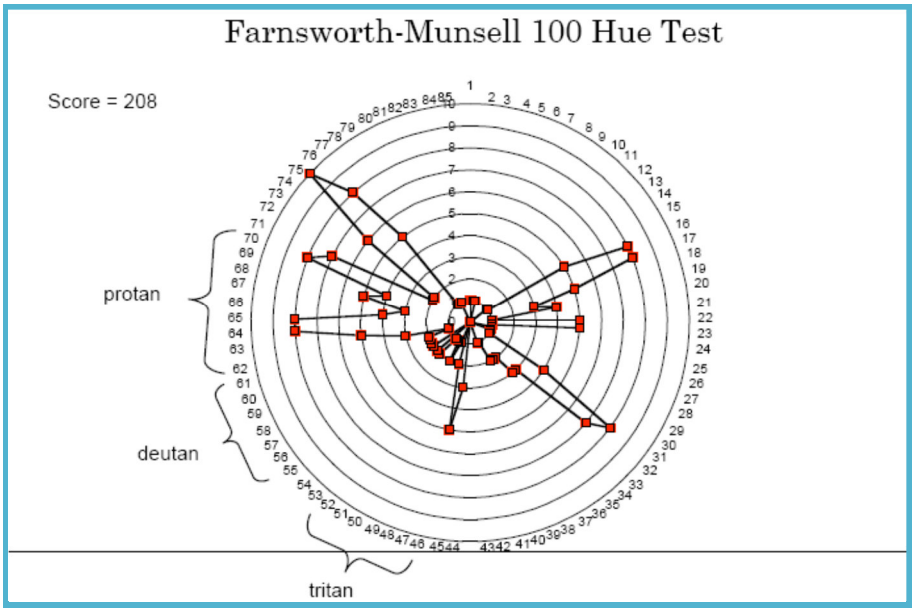

Figure 26-1 *Example computer plot of one patient's Hundred-Hue test*

SATURATED AND UNSATURATED D-15 TESTS

The D-15 test is an abbreviated version of the Hundred-Hue test, so it is easy to use, fast and can diagnose all three categories of colour anomaly (protan, deutan, tritan). It can also grade the severity of the defect. This is the test that has been produced by the NSU Optometric Students Association, and has been called the **Oklahoma Colour Vision Test**.

Like the Hundred-Hue test, the colour samples (15 of them) must be arranged in hue order, starting with a reference cap. The order of the caps is recorded on a dot-to-dot style recording sheet. See Borish Figs. 9-37, 9-39, 9-45 for examples of D15 test results for patients with normal and anomalous colour vision.

The dots on the recording sheet are based on the CIE chromaticity diagram (Schwartz, 2004 Fig. 6-13; Borish Fig. 9-36). The reference lines on the recording sheet are colour confusion lines, and they help diagnose the type of colour anomaly. If the patient is a protan, deutan or tritan, lines will cross the circle with a slope that parallels the reference line for the particular anomaly.

On this test, one cross-over is considered a fail. Table 26.2, below, summarizes criteria from Borish, 2006: Chapter 9, for interpreting other misplacements. The desaturated test is more difficult and is a more sensitive test for a colour anomaly, so it should do a better job of detecting subtle changes in colour vision that might accompany a disease.

Table 26-2: *Pease's (Borish, 2006: Chapter 9) Pass/fail criteria for the D-15 tests*

TEST RESULT	CROSS-OVERS	TWO OR GREATER PLACE ERROR	SINGLE PLACE ERROR
Fail	1	1	2

NAGEL'S ANOMALOSCOPE

The anomaloscope is the most accurate test for diagnosing protan and deutan defects. It can precisely diagnose red-green dichromats and differentiate them from anomalous trichromats. To understand and be able to interpret the anomaloscope results, you must have a good understanding of colour vision and colour vision anomalies. That may be one reason that anomaloscope questions frequently appear on the national board exam.

Figure 26-2: *A modern version of the anomaloscope manufactured by the Oculus company in Germany. (http://www.oculus.de/english/)*

ANOMALOSCOPE CONFIGURATION

The patient looks into the anomaloscope and views a bipartite field, as shown in Figure 26-3

The mixture field

- Upper half of the bipartite field
- Composed of a mixture of two wavelengths - 670 nm (red) and 546 nm (green)
- Patient adjusts the relative mix of these two colours using a control knob that ranges from a value of 0 for pure green to 73 for pure red
- Total luminance remains constant for all mixture settings
- For a normal trichromat (with normal a V(λ) function), the brightness will appear constant for all settings

The test field

- Lower half
- One fixed wavelength - 590 nm (yellow) light
- Luminance is adjustable from a scale of 0 (dim) to 35 (bright)

NAGEL'S ANOMALOSCOPE (CONT.)

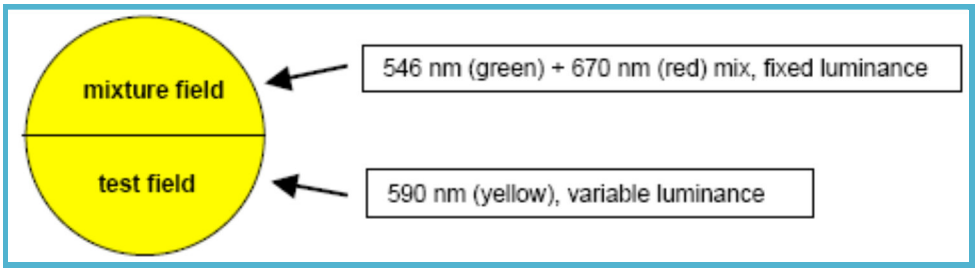

Figure 26-3: *Configuration of the Nagel anomaloscope stimulus*

All three wavelengths used in the anomaloscope are above 545 nm, so it tests vision over the range in which trichromats are dichromatic, and protanopes or deuteranopes are monochromatic. See Schwartz, 2004 Fig. 6-15, which illustrates the concept of red-green colour mixing on the CIE chromaticity diagram. All three wavelengths fall on a colour confusion line that is common for protans and deutans. Colour mixing in this range is based on the **Raleigh equation**, which specifies the amount of red and green you need to mix in order to obtain yellow.

NORMAL TRICHROMAT RESPONSE

1. The patient's first task is to adjust the mixture of the upper field until it matches the hue (yellow) of the lower field. The mixture field usually is set to a value of about 45. The range is 0-73
2. Then he/she must adjust the luminance of the lower (test) field until it matches that of the upper field. The test (lower) field is usually set to about 17. The range is 0-35

This is a simple colour matching experiment. Recall that a dichromat can achieve a metameric match using 3 wavelengths. In this case, the three colours are red + green above and yellow below.

GENERAL PRINCIPLE OF COLOUR MATCHING FOR A RED-GREEN DICHROMAT

Protanopes or deuteranopes are monochromatic over the range of wavelengths used in this test, so they can achieve a metameric match using only two colours. Dichromats can match any *two different colours* by adjusting their relative luminances.

If the mixture field is set to 0 (pure green), a dichromat will be able to adjust the test field luminance and make the lower yellow and upper green match.

If the mixture field is set to 73 (pure red), he/she will still be able to adjust the lower test field luminance to make the yellow and red appear to match. In fact, he/she will be able to set the mixture field to any setting and it will be possible to match the lower field to it by adjusting the luminance of the lower field.

DEUTERANOPE RESPONSE

Recall that the luminosity function for deuteranopes is nearly normal (Schwartz, 2004 Fig. 6-3). Therefore, the different wavelengths vary in terms of their perceived brightness in the normal way. The normal setting for the lower test field is 17, therefore deuteranopes will set the luminance near this. Recall that the mixture field maintains a constant luminance for all mixtures.

- For deuteranopes, any mixture will match the lower field
- Deuteranopes keep the intensity setting for the lower field at about 17 for all mixtures

NAGEL'S ANOMALOSCOPE (CONT.)

PROTANOPE RESPONSE

The V(λ) function for a protanope is shifted toward shorter wavelengths. Therefore longer wavelengths (i.e., red) appear dimmer than normal, and shorter wavelengths (i.e., green) appear brighter. If the upper (mixture) field is set to red, the deuteranope will decrease the test field luminance. If the upper (mixture) field is set to green, he/she will increase the lower field to match it.

- For protanopes any mixture can match the lower field, but ...
- They will have to adjust the brightness depending on the mix
- For high (red-strong) mixtures, they will set brightness lower than normal (17)
- For low (green-strong) mixtures, they will set brightness higher than normal

Q. How should this instrument work with a tritanope?

COLOUR MATCHING FOR AN ANOMALOUS TRICHROMAT

The anomalous trichromat will show a mixture setting that is a bit displaced from the normal setting of 45. The **deuteranomalous** person will be relatively green-weak compared to a normal trichromat. He/she will need to compensate by increasing the green content of the mixture field. Therefore his/her mixture setting will be lower than 45. For example, some value between 0 and 45.

The deuteranomalous patient will have a normal luminosity function, so he/she will set the test field luminance to about a normal value of 17. Since his/her wavelength discrimination is worse than a normal trichromat, he/she will be less precise than a normal person and have a relatively broad range of mixture settings over which he/she can match the upper and lower fields.

- Deuteranomalous dichromats add more green to the mixture
- Their mixture setting will be more variable than a normal
- They will set the brightness to a normal level

The **protanomalous** trichromat will be relatively red-weak. Therefore, in order to match the lower yellow field, he/she will want to add more red to the mixture than a normal trichromat. His/her setting will be greater than 45; for example, 45-73. Since the protanomalous person sees red as dimmer than normals, though the hue may match the test field, it will appear to be dimmer than it would appear to a normal trichromat. He/she will therefore set the test field setting to some value lower than 17.

- Protanomalous dichromats add more red to the mixture
- Their mixture setting will be more variable than a normal trichromat
- They will set the brightness to a lower-than-normal level

Know and understand Schwartz, 2004 Fig. 6-16.

SELECTED READING/REFERENCES

- Schwartz SH. **Visual Perception - A Clinical Orientation, 3rd Edition**. Appleton & Lange, Stamford, Connecticut, 2004
- Benjamin WJ (ed). **Borish's Clinical Refraction, 2nd Edition**. Butterworth-Heinemann,Philadelphia, 2006