

Lecture 33 – Anomaloscope

THE NAGEL ANOMALOSCOPE

The anomaloscope is considered 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 color vision and color vision anomalies. That may be one reason that anomaloscope questions frequently appear on the national board exam.



Figure 1. A modern version of the anomaloscope manufactured by the Oculus company in Germany. (<http://www.oculus.de/english/>)

Stimulus configuration

The following discussion is based on a well-known version of this instrument, the Nagel anomaloscope, which is described in your textbook. The patient looks into the anomaloscope and views a bipartite field, as shown in Figure 2, below.

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 colors 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 $V(\lambda)$ 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).

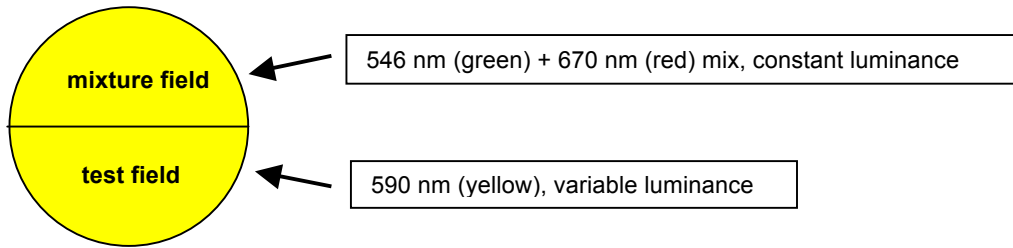


Figure 2. Configuration of the Nagel anomaloscope stimulus.

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 Figure 3 (Like Schwartz Fig. 6-17), which illustrates the concept of red-green color mixing on the CIE chromaticity diagram. All three wavelengths fall on a color confusion line that is common for protans and deutans.

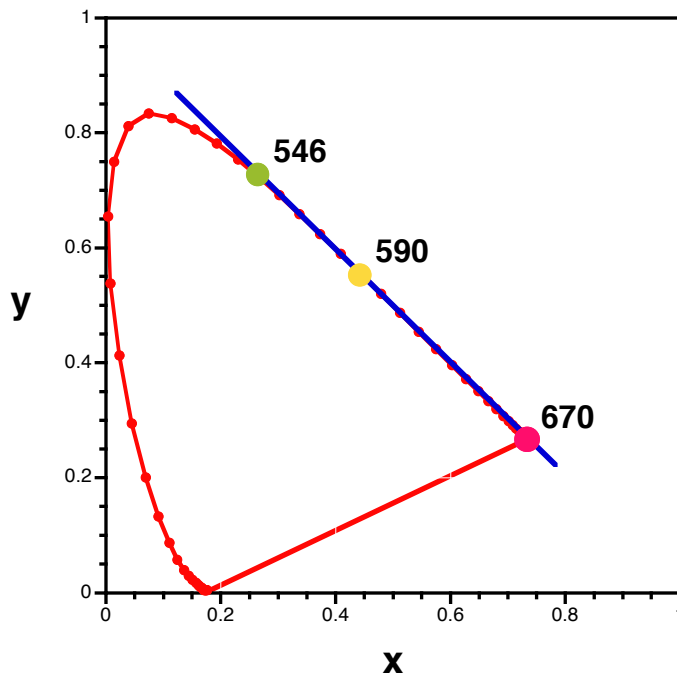


Figure 3. CIE color matching with the anomaloscope.

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 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 color matching experiment. Recall that a dichromat can achieve a metameric match using 3 wavelengths. In this case, the three colors are the red + green above and the yellow below. **And recall that people with normal color vision are dichromats in this wavelength range.**

General principle of color matching for a R-G 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 colors. Dichromat (monochromat in this range) can match *any two different colors* 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 will still be able to adjust the lower test field luminance to make the yellow and red appear to match. In fact, he 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 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.

Protanope response

The $V(\lambda)$ 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 will increase the lower field to match it.

- For protanopes any mixture can match the hue of 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?

Color 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 will need to compensate by increasing the green content of the mixture field. Therefore his mixture setting will be lower than 45. For example some value between 0 and 45. **Since his wavelength discrimination is worse than a normal trichromat, he will be less precise than a normal person and have a relatively broad range of mixture settings over which he can match the upper and lower fields.**

The deuteranomalous patient will have a normal luminosity function, so he will set the test field luminance to about a normal value of 17. **To summarize,**

- 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 will want to add more red to the mixture than a normal trichromat. His 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 will therefore set the test field setting to some value lower than 17.

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

Summary – normal trichromat

- The anomaloscope helps diagnose red-green dichromacy and red-green anomalous trichromacy.
- It performs a 3-hue color matching experiment (two pure spectral hues mixed to match a third). Specifically, 546-nm green and 670-nm red are mixed to match 590-nm yellow
- In this range of wavelengths, trichromats are actually dichromatic.
- A normal trichromat (dichromat in this range) can achieve a metameric match with three hues, but not with two. You cannot fool them into thinking that two different hues are the same color, no matter how you adjust their brightnesses. That is, neither the 546-nm nor the 670-nm lights will ever match the 590-nm light. Only the correct mix of 546-nm light + 670-nm light will appear to match 590 nm.

Diagnosing dichromacy

- Over the range of wavelengths used, a person with red-green dichromacy is monochromatic.
- These patients will be able to achieve a metameric match with two hues. You can fool a protanope into matching either a 546-nm or 670-nm light to a 590-nm light by adjusting their relative brightnesses. A deuteranope can also be fooled into incorrectly matching those hues with 590-nm. Any in-between mixture will also appear to match the hue of the lower test field.

Differential diagnosis of protanopia versus deuteranopia

- You can differentiate between protanopes and deuteranopes based on the way they adjust the brightness setting.
- Recall that the protanope's $V(\lambda)$ function is abnormal, but the deuteranope's $V(\lambda)$ function is normal.
- The 670-nm light will appear dimmer than normal for the protanope. The 546-nm light will appear brighter than normal for the protanope.
- Therefore, when matching 670-nm light to 590-nm, the protanope will set make the test light (590-nm) dimmer than normal.
- When matching the 546-nm light to 590-nm, the protanope will make the test light (590-nm) setting brighter than normal.
- If the brightness settings are normal, the dichromat is a deuteranope.

Anomalous trichromats

- Protanomalous and deuteranomalous trichromats make close-to-normal settings for both the mixture and brightness.
- Since they are not dichromats, they will not be fooled into matching pure 546-nm light or pure 670-nm light with 670-nm light. However, their mixture setting will be slightly incorrect compared to trichromats.
- Consider deuteranomalous trichromats as being "green-weak." To compensate, they will tend to add more green to the mixture than normal.
- Consider protanomalous trichromats as being "red-weak." To compensate, they will tend to add more red to the mixture than normal.
- As described above, protans (including protanomalous trichromats) will make abnormal brightness settings. This also helps to differentiate between protanomalous versus deuteranomalous trichromats.

Know and understand Schwartz **Fig. 6-19**.

Example question from the Optometry Exam Review Book:

Question #2. A color-deficient person looks in an anomaloscope and does not accept a color-normal's match? The nature of the person's deficiency is:

- a. protanomaly
- b. deuteranopia
- c. protanopia
- d. tritanopia

11. A patient mixes monochromatic green and red lights to obtain a metameric match with monochromatic yellow. If he thinks any red-green mixture looks the same hue as the yellow light, which of the following diagnoses is/are possible?

- a. protanomaly

- b. protanopia
- c. deuteranomaly
- d. deuteranopia
- e. none of the above

12. In addition to the adjustment described in Question 11, assume that the patient reduces the radiance of the yellow light below normal when the mixture setting is pure red, and increases the radiance above normal when the mixture is set to pure green. Which of the following diagnoses is/are possible?

- a. protanomaly
- b. protanopia
- c. deuteranomaly
- d. deuteranopia
- e. none of the above

13. For which of the following anomalies would the patient accept normal mixture and luminance settings?

- a. protanomaly
- b. protanopia
- c. deuteranomaly
- d. deuteranopia
- e. none of the above

14. Suppose the mixture setting contains a slightly greater-than-normal amount of green but the luminance setting is normal. He probably has ...

- a. protanomaly
- b. protanopia
- c. deuteranomaly
- d. deuteranopia
- e. none of the above

15. Suppose the mixture setting contains a slightly greater-than-normal amount of red but the luminance setting is significantly greater than normal. He probably has ...

- a. deuteranomaly
- b. deuteranopia
- c. protanomaly
- d. protanopia
- e. none of the above