LEA Color Vision Testing

To The Tester

Quantitative measurement of color vision is an important diagnostic test used to define the degree of hereditary color vision defects found in screening with pseudoisochromatic tests and in evaluating deficient color vision from acquired disorders.

The *Panel 16 Quantitative Color Vision Test* is unique from other quantitative color vision tests because it uses large cap sizes, which gives more information about color vision function both in normally sighted and low vision individuals.

The *Panel 16 Color Vision Test* consists of a set of a "pilot" of "pilots" and 15 test caps of the same hues as in the Farnsworth Panel D-15 Test. The diameter of the stimulus area is 3.3 cm (1.3 in).

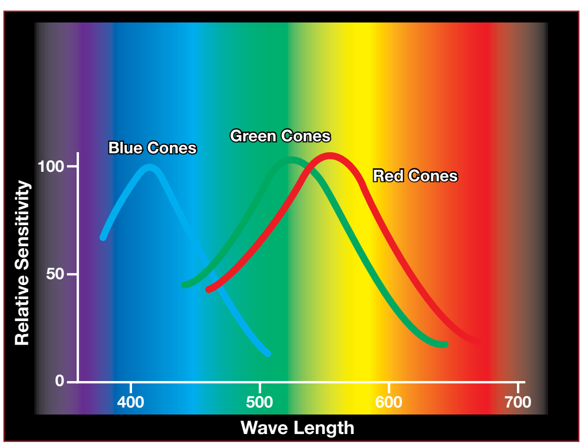

Figure 1

1. Verriest G. Van Laethem J.,Uvijel A. A new assessment of the normal ranges of the Farnsworth-Munsell 100 hue test scores. Amer J Ophthalmol 1982; 93:635-642.

The stimulus size can be reduced by using a dark gray restriction ring with an opening of 1.2 cm (.47 in) in diameter.

The large stimulus area corresponds to the visual angle of 3.8° when testing at 50 cm (20 in) and to 6.3° when testing at 30 cm (12 in). The small stimulus is seen as the recommended 1.5° stimulus at a distance of 46 cm (18 in). When testing young children or persons with low vision, the distance is often much shorter than 30 cm, thus the size of the large stimulus becomes 9.5° at 20 cm (8 in) and 19° at 10 cm (4 in).

The color surface has a protective coating, which decreases the risk of the stimulus area getting smudged[1].

Color Vision

Neural Functions in Color Vision

Perception of color is based on three different neural functions:

1. Absorption of light energy in three types of cone cells of the retina;
2. Comparison of the absorption rates in these three different cones; and
3. Abstraction of color by cerebral cortex from this comparison.

Absorption curves of the three cone populations (*Figure 1*) show that each cell absorbs light energy within a wide range of the color spectrum. Neural impulses coming from all three types of cones selectively activate the cells of the ganglion cell layer from where the impulses are transferred via optic nerves and optic radiations to the primary visual cortex, from there the information moves to color specific areas for further analysis.

The three types of cone cells are the L-(long wave-length sensitive or "red") cones, the M-(middle wave-length sensitive or "green") cones, and the S-(short wave-length sensitive or "blue") cones. The L- and M-cones constitute the majority of cones, 85 to 90 percent. The distribution of cones varies in different locations of the retina: S-cones are not present in the very center of the fovea and are concentrated on a circular area, approximately 2° from the center of the fovea.

Differences in cone distribution is probably not important because the integration and comparison of different cone types (i.e., L versus M, and separately, L and M versus S) is probably made on a similar basis in each unit area of color space. The absence of S-cones in the foveola is probably compensated for within the unit area of color space that includes the foveola.

Results of color vision tests vary as a function of the size of the color stimulus because of the uneven distribution of the cones. In the peripheral retina, we all have "defective" color perception of small test stimuli. In everyday life, we are not aware of variations in color perception in the different parts of the visual field, because of the complicated summation functions of the brain.

Clinical Evaluation of Color Vision

When a person's color perception is deviant from that of the general population, the disorder may be either a congenital or an acquired color vision defect.

Congenital Color Vision Defects

Color vision testing is designed for assessing children and adults who have congenital color vision deficiencies. Often, the deviations from normal color vision are so mild that they do not have any practical consequences, especially in childhood if the child's difficulty is understood by the teacher and parents. Adults with color vision defects should also be aware of this characteristic in their vision because some jobs require good, or even perfect, color vision.

In congenital color vision defects, the abnormality is usually in the structure and function of a cone pigment (rarely in more than one).

Figure 2

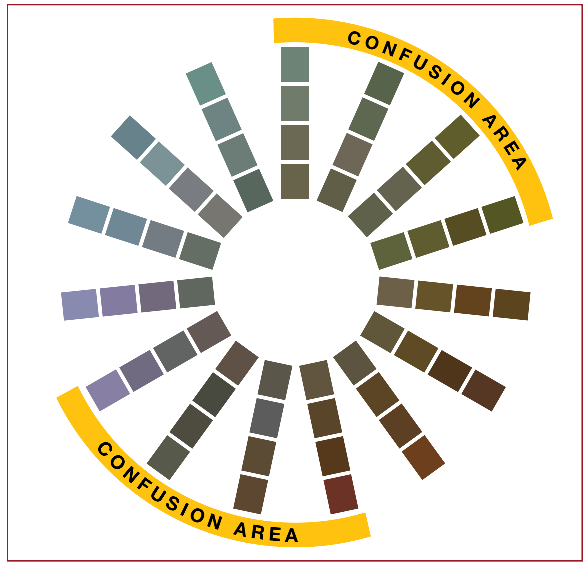

Figure 3

Red-green color vision defects are X-chromosomally inherited, thus more common in males (8%) than in females (0.4%).

A normally sighted person sees all colors of the spectrum (*Figure 2*) whereas a person with a red-green defect (*Figure 3*) has a grayish confusion area (In brackets in *Figure 3*) within which he or she does not see the difference between some shades of red and green and misses them.

A. Colored surfaces in this figure represent all spectral colors, saturated at the outer end of the spokes.

B. This illustration depicts how the picture in *Figure 2* is seen by a person with a deutan defect. Green tones and the opponent tones of purple-red are seen as dull and therefore easily confused with each other. Since these colors are on the opposite sides of the color circle, there is an "axis" of deficiency across the color circle. The color space of this person is blue-yellow with confusion of colors in the red-green axis. Individual variations in confusions of hue are great.

Color vision defects are generally screened using pseudoisochromatic Ishihara-type tests. They are designed to be highly sensitive and usually miss only a few mild cases. Some individuals who do not have a color vision defect may fail color vision screening tests. Therefore, the degree of color vision deficiency should be evaluated using quantitative tests. Statements or diagnosis of color deficiency should never be based on screening tests alone. Widely used sorting tests of the Farnsworth Panel D-15 type are not sensitive to acuity loss and contrast sensitivity loss.

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Deutan Defect

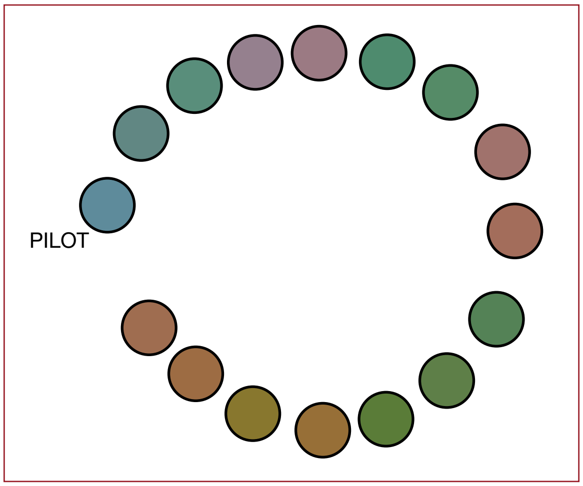

Figure 4

A. The caps are arranged so that "closely similar" caps are next to each other (*Figure 4*).

B. Results drawn on the recording sheet show crossings in the deutan axis (*Figure 5*).

In sorting tests, the color defective person arranges the caps in an order different from that of a person with normal color vision. Colors that look similar to the person with a color defect are placed next to each other.

In clinical evaluation of adult subjects the size of the stimulus should be 1.5° of angle. This means a working distance of 50 cm (19.5 in) with most tests. If the subject bends closer, the stimulus area increases. Standard evaluation is done with the small stimulus size. Subjects with mild color vision defects may discriminate and sort colors normally when large stimuli are used. For functional purposes, it is of interest to test with large size caps as well. When testing children, it is helpful to start with the large stimuli and proceed testing with small cap sizes.

Acquired Color Vision Defects

Color vision defects (also called dyschromatopsias) that are caused by diseases or trauma may affect cone cells, inner retinal layers, optic nerve fibers or the visual cortex. The structural and functional changes may be patchy or diffuse and may affect vision in one eye more than in the other eye. For diagnostic purposes, the eyes are tested separately. For functional purposes, binocular measurements are more informative.

Macular lesions often cause a defect with the blue-yellow, or tritan, axis since there are fewer S-cones than L- and M-cones, and they are concentrated around the edge of the fovea. However, when the lesion is small or patchy, either there is no axis present or it varies from day to day.

Screening tests that are designed for revealing red-green defects do not pick up acquired defects in the blue-yellow axis. A few screening tests have plates for the blue-yellow defects.

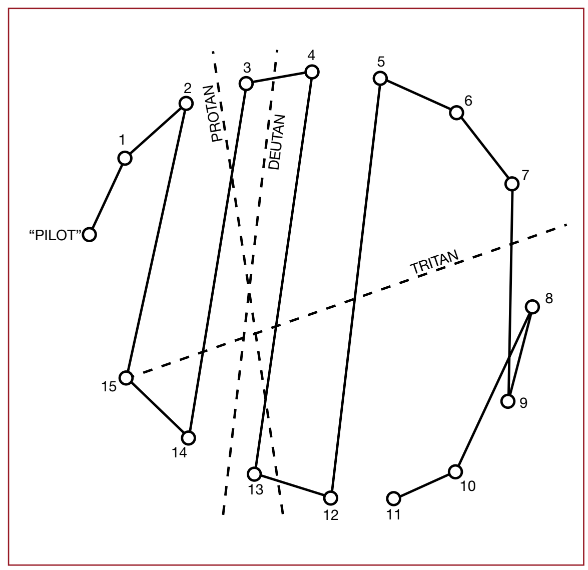

Figure 5

Results in quantitative testing vary as a function of stimulus size. This is more pronounced in acquired color vision defects than in congenital color vision defects. Results from testing with small stimuli depict function in the preferred retinal locus used for fixation, whereas results from testing with large stimuli give information on color perception in everyday life.

Color of an adjacent surface may alter the perceived brightness and hue of nearby color surfaces. This causes an additional confusing factor in assessing vision for ADL (Activities of Daily Living).

In diagnostic evaluation the tester should be aware of the fact that reduced retinal illuminance due to cloudiness of the cornea, lens or vitreous distorts test results. In such cases, increased illumination may decrease the degree of the defect or make it disappear.

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Illumination should be either natural, overcast daylight at a window facing the northern sky (in Northern Hemisphere) or artificial light with color temperature of 6774 K (Standard Illuminant C).

Testing Procedures

Older Children And Adults

Adult testing techniques are used when children or adults are asked to choose a cap that is closest in color to the previously chosen cap. This is surprisingly easy for children. Generally, even five-year-old children with normal color vision are able to arrange the whole test quickly and with no hesitation (*Figure 6*). A child or an adult person may train the test situation with the color vision game. During the games the color confusion areas will be noticed. The degree of deficiency must be then investigated using the Panel 16 test.

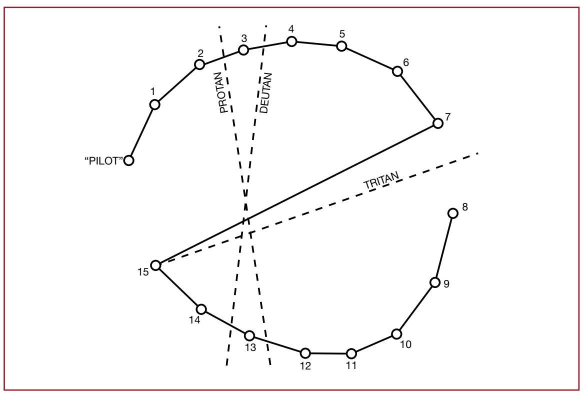

Figure 6

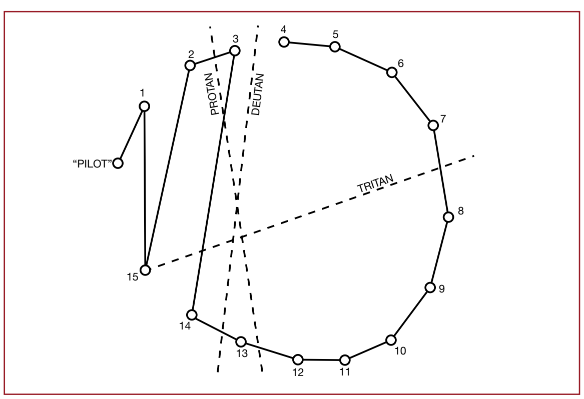

Figure 7

Note that the crossing from cap #7 to cap #15 is accepted as normal because of the relatively large difference between caps #7 and #8.

Figure 6 shows normal findings. The person has sorted the caps from "pilot" to #7 correctly, found the cap #15 to be closest to cap #7 in color and then sorted the rest of the caps correctly.

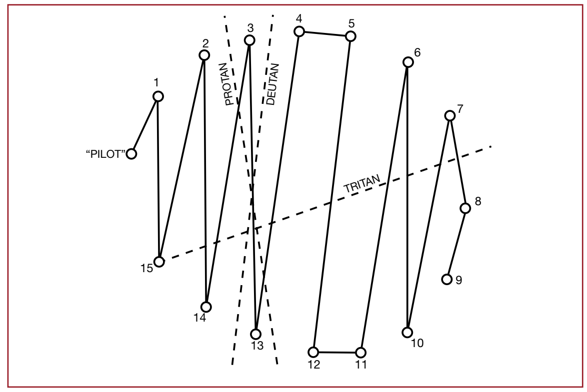

Figure 8

Children and some adults with color vision deficiencies are more difficult to test because the abnormal arrangement could be due to misunderstanding how to do the task. When a normally sighted child has problems in naming colors and repeatedly shows "confusion areas" in the same axis, (deutan or protan), the diagnosis of inherited color vision defect can be made, even in children as young as five to six years of age. If the child seems to be hesitant in arranging the caps, the technique described for testing young children can be used at any age, including adults.

Color vision deficiencies should be known at school as early as possible so that the child is not misunderstood. In the early teens color vision tests are needed for advice in career planning (*Figures 7* and *8*).

Figure 7 shows three crossings across the color circle. The person sorted the caps to the following order: "pilot", 1-15-2-3-14, then the rest correctly. The confusions are between the blue end and the purple end of the color circle.

Figure 8 shows severe deutan defect is noticeable in this recording. The order of caps is: "pilot", 1-15-2-14-3-13-4-5-12-11-6-10-7-8-9.

Young Children

Children who do not understand the task of hue arrangement can be tested in a play situation.

1. Every third cap of the test (*Figure 9*) is placed on the table (Caps "pilot," 3, 6, 9, 12, and 15 from Set A). The child is given the same numbered caps from the matching second set, Set B, one at a time and asked to find the cap that matches the cap in his/her hand from Set A on the table. Usually there is an obvious difference in the behavior of a child with normal color vision and one with a color vision defect. The former finds the matching color with no delay, the latter keeps choosing between different colors. The caps should preferably not be in the order of a normal circle but randomly placed on the table.

   Caps are randomly arranged in front of the child (*Figure 9*). Caps are: 3, 6, 9, 12, 15 and the "pilot." The child's task is to match colors by moving caps of the other set, one by one, here it is #9.

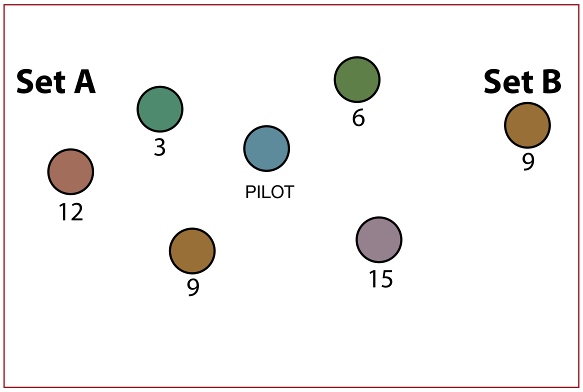

Figure 9

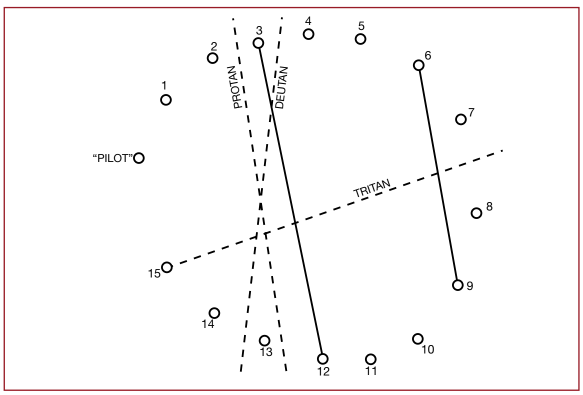

Figure 10

The findings are marked on the recording sheet (*Figure 10*)

2. When the child is accustomed to playing with colors, the number of caps on the table increased to cover two-thirds of the total caps (Pilot, 1, 3, 4, 6, 7, 9, 10, 12, 13, and 15). The game can be played as before (i.e., the child tries to match the colors). The confusions are revealed as in the previous situation.
3. Make the test situation more difficult by using only one set of caps. Place one-third of the caps aside (2, 5, 8, 11, and 14) and the remaining two-thirds of the caps in random order, in front of the child (*Figure 12*). Give the child one of the five caps that were set aside and ask the child to select among the caps on the table, the two caps that are closest in color to the one he or she has. When the comparison is made, return the selected caps among the others in front of the child. Move the caps to keep their order random. The matched cap is set aside and the next cap is given to the child. A child may use a cap more than once. The child has matched #2 with #3 and #15; #5 with #6 and #12; #8 with #7 and #9; #11 with #9 and #12; and #14 with #3 and #13 (*Figure 13*). The findings are recorded on the recording sheet (*Figure 14*).

Set A		Set B
3	< - >	12
6	< - >	9
9	< - >	6
12	< - >	12
15	< - >	15
3	< - >	3
Pilot	< - >	Pilot

Figure 11. Comparisons made by the child

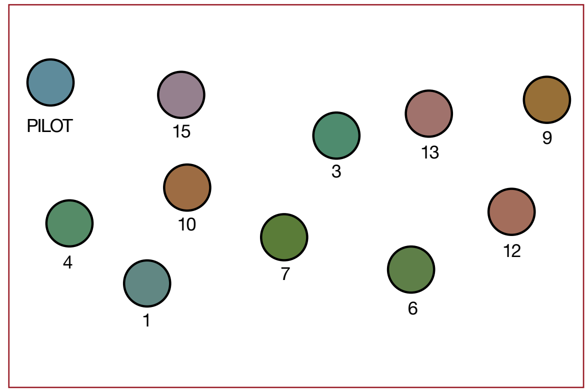

Figure 12

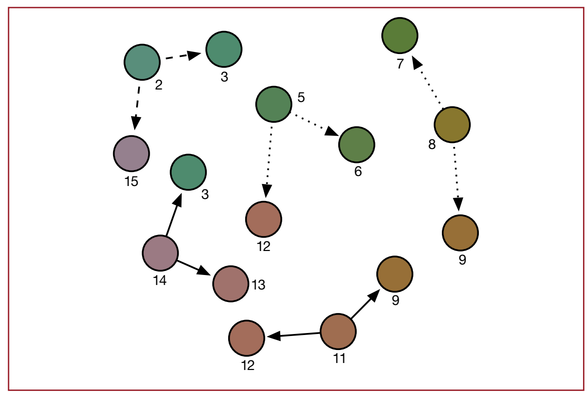

Figure 13

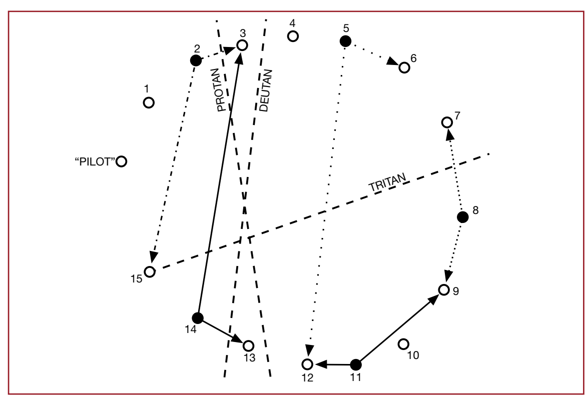

Figure 14

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By not arranging the whole circle at once in this play situation, color confusions are found as short sequences of the circle. By varying the thirds of the caps on the table, the axis confusions can be easily found. When tested with the large stimulus, the degree of the defect may be different from the results of testing with a small stimulus2,3.

Testing can also be made easier by using the following technique: Show the person that 'I would arrange these colors in this order' and place the caps one after the other in the correct order. Then say ' this was my way of arranging, lets sort the caps together'. Place the Pilot cap at the left edge of the test area and say ' this is always the first cap'. Then take it and move it above the other caps that are mixed on the table and ask 'which one of these caps has nearly the same color?'. When the child chooses one - correct or incorrect - place the Pilot on its place and use the chosen cap the same way as the Pilot cap to find the next cap. Go on like this until all caps are sorted. If one or two caps are left over, tell the child 'these we forgot to sort, where would you place them?'. When the child/person does not need to concentrate on the motor functions, sorting the colors becomes easier.

Acquired color vision defect tested with different sorting test

Acquired patchy defects of central visual field cause varying losses of color vision in different parts of the central visual field and result in different kinds of confusions, when either the saturation (the amount of color mixed with white) or the size of the test is varied.

A person who makes several major errors that give rise to lines crossing the color circle on Lanthony's Desaturated Test (weak pastels colors mixed with white, *Figure 15*) may perform better on the regular Panel D-15 or Panel 16 small stimulus testing (*Figure 16*) and still better on the Panel 16 test when large stimuli are used (*Figure 17*). This may be because testing with a larger stimulus covers more area of a normally functioning retina and thus the person can more easily compare the caps with larger surfaces.

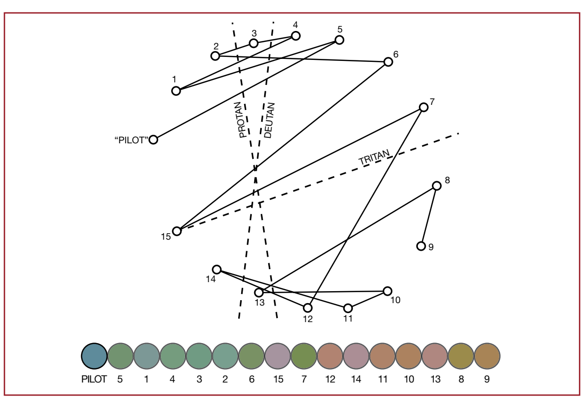

Figure 15

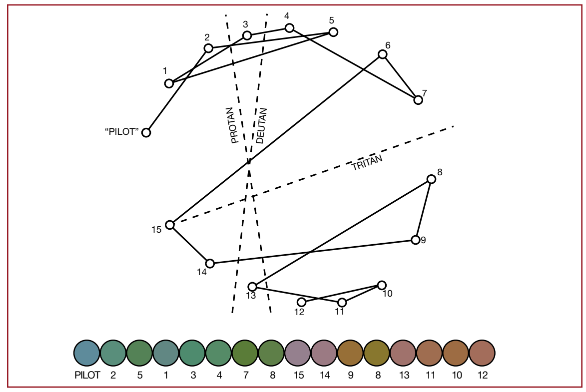

Figure 16

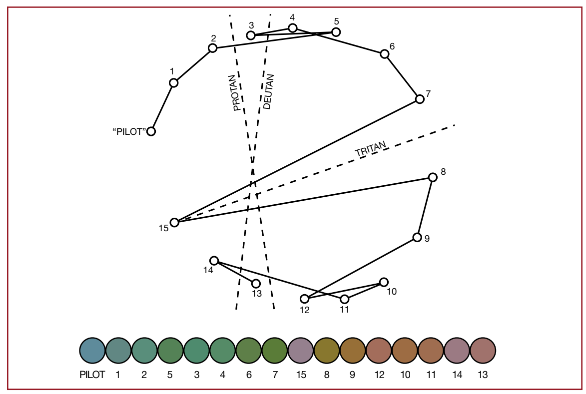

Figure 17

Interpretation of Panel 16 Test Results

Minor Confusions

Errors between caps close to each other are common, even in persons with normal trichromatic color vision. *Figure 18* shows an example of two minor confusions; #5, #6, #11 and #12 were misplaced.

Crossings Across Color Circle

Confusions between colors farther apart from each other on the color circle (i.e., across the color circle) also occur in normal color vision, especially from cap #7 to #15 (Refer to *Figure 6*). Less than four (4) crossings are usually accepted as normal if there is no definitive axis. Confusions occurring regularly in a certain direction across the color space or axis (*Figure 19*: 3-14, 13-4, 5-12, 6-11) reveal the type of color vision defect (*Figure 19* deutan defect). Note that cap #15 was "left over;" the patient wanted to place it on the wrong side of the "pilot." In a situation like this, it is best to accept the result as it is, mix the caps and retest. More than four (4) crossings in an axis are recorded as deficient color perception in that axis.

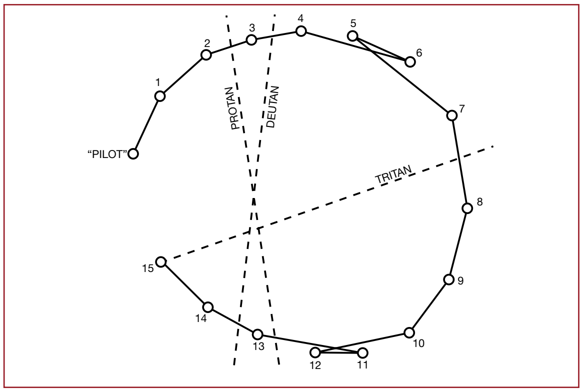

Figure 18

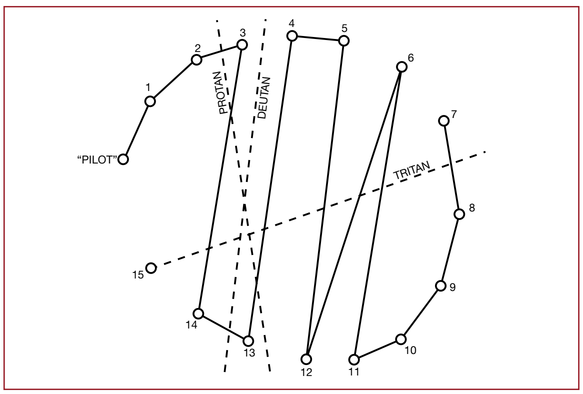

Figure 19

The border between mild and moderate color defects is not well defined. The border between moderate and severe color vision deficiencies is usually placed at ten (10) crossings. Different employers have different limits for confusions tolerated for specific tasks.

The three axes of color vision defects protan, deutan and tritan are sometimes called red-blindness, green-blindness and blue-blindness, but these names are confusing. Persons with color vision deficiencies are not color blind, they just confuse some colors. For example, protanopes and deuteranopes, both confuse some blue and purple shades and certain brown, red and green shades. Tritanopes match violet with green.

When testing young children, we do not get the number of "crossings" across the color circle, as stated above, because the child is not making complete color choices in one trial. However, we do get important information about whether or not the child confuses some colors (*Figure 19*).

Using the Recording Form

Draw the line connecting the numbers in the order which the person has arranged the caps (*Figure 4*). The four diagrams on the Recording Form are used to record test results for: the training trial, binocular test, right eye and left eye. If only the binocular test is done, or the person has only one eye, the results can be recorded simply by writing down the numbers of the caps in the order that they are arranged.

If the tester wants to mark the errors, the errors can be circled. For example *Figure 5* would look like this:

P – 1 ⊖ 15 ⊖ 2 – 3 ⊖ 14 – 13 – 12 – 11 – 10 – 9 – 8 – 7 – 6 – 5 – 4

This is also the easiest way to record results in a case history. If the test is done twice, as it often is, the results can be written under each other to make it easier to see any variations. For example *Figure 5* would look like this:

P – 1 ⊖ 15 ⊖ 2 – 3 ⊖ 14 – 13 – 12 – 11 – 10 – 9 – 8 – 7 – 6 – 5 – 4

P – 1 ⊖ 15 – 14 ⊖ 2 – 3 – 13 – 12 – 11 – 10 – 9 – 8 – 7 – 6 – 5 – 4

(Retest on the person in *Figure 5*)

In this case, there is only a mild uncertainty in the arrangement of the colors, no stable axis and less than four crossings.

When recording the results as matched pairs, write them down as in *Figure 11*. The crossings can be marked on the diagram on the Recording Form as in *Figure 12*.