Article • The FM100-Hue Test Can Detect Poor Color Vision Undetected by Color Vision Screening

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ABSTRACT

Background: The Farnsworth-Munsell 100-hue test (FM100-hue) is a color-arrangement test wherein a patient must arrange 85 caps into color order. It is a well-known and widely accepted test, but it is not often used in primary eye care practice because it takes a fairly long time (about 10 minutes) to administer. However, this case report will show the usefulness of the test where other tests of color vision were not able to give a clear picture of a patient's color vision issue.

Case Report: A 17-year-old Caucasian female presented with a complaint of having trouble distinguishing different shades of similar colors. The patient had a comprehensive eye exam a week prior to this visit, which did not reveal any significant findings. No family history of color vision deficiency was reported. She passed all color vision screening book tests. Additional tests, including the Farnsworth D15, were passed, but with some anomalies. The FM100-hue test was definitively failed and showed a severe (total error score = 372), non-specific color vision issue with errors in every part of the color circle. The patient was diagnosed as likely having genetically normal color vision, but with very poor hue discrimination.

Conclusion: The case shows that the FM100-hue test can identify non-specific color vision issues, even when other color vision tests cannot, and the test has utility in clinical practice.

Keywords: color vision, FM100-hue, color vision deficiency

Introduction

Color vision deficiency (CVD) is a clinical condition that can be congenital or acquired. Congenital cases are primarily inherited in an X-linked recessive pattern, occur in the absence of any other vision function issue, are non-progressive, and affect up to 8% of males and 0.5% of females.[1,2] Congenital cases of CVD are grouped into anomalous trichromacy and dichromacy, the former being milder than the latter. Acquired cases of CVD are the result of ocular pathology or toxicity, are typically present with other deficits in vision function like decreased visual acuity, and can be asymmetric and progressive.

Potential cases of CVD, whether congenital or acquired, are screened for during eye examinations using color vision book tests, also known as pseudo-isochromatic plate tests.[1] These tests have high sensitivity and specificity for detecting patients with color vision issues as color deficient and also for identifying patients without color vision issues as color normal.[3-5] The book tests are compared against the anomaloscope, the gold standard for congenital cases of CVD, in order to determine their accuracy.[1] If a patient were to fail one of these screening book tests, the general clinical guidance is next to perform a Farnsworth D15 test, which is a cap arrangement test.[1,6] The Farnsworth D15 test can identify the diagnostic type of the CVD and provide an indication of severity of the CVD, both aspects that a color book test like an Ishihara does not do well.[1] There are other cap arrangement tests, such as the Lanthony desaturated D15 and the Farnsworth-Munsell 100-hue (FM100-hue) test.[1] The Lanthony test is typically used to categorize severity further if a patient has failed a book test but performs perfectly on the Farnsworth D15 test.[7,8]

The FM100-hue test was the precursor to all cap arrangement tests and consists of 85 caps that form a color circle from purple to red.[9] The 85 caps are presented to a patient in 4 sets of 21-22 caps at a time, each set representing about a quarter of the color circle. For each set, the test commonly has two pilot caps that are used as color references to denote the start and end of the cap sequence. Patients are presented the 21-22 caps that lie between the pilot

caps in random order and asked to place them in color order. Once the patient has repeated this process for each of the 4 sets, the examiner records the sequence in which the patient placed the caps, and then the examiner can determine a total error score.[9] The patient's total error score is then compared against age-similar normative data.[10,11] The FM100-hue test is among the most time-consuming of the clinical color vision tests to administer and for this reason is not often used in clinical practice.[1] Despite the challenges regarding test time, the FM100-hue test has several uses. It can be used to quantify the color vision aptitude of those with normal color vision. It can also be used to supplement other color vision tests in that it can be used to explain to a patient with CVD the specific parts of the color circle that are most troublesome.

Case Report

A 17-year-old Caucasian female presented to our office for a color vision evaluation. Her chief complaint was trouble distinguishing different shades of similar colors. One specific example she reported was that she could not tell the difference between a red and a pink button on the screen of a computerized cash register at her work. The patient had a comprehensive eye examination including a dilated fundus examination in our clinic only a week prior, and it did not reveal any significant findings.

At this visit, uncorrected visual acuity was 20/20 in each eye. No family history of color vision deficiency was reported. All color vision tests were viewed using a Richmond Illuminator (an illuminant C-equivalent light source) at a light level of 500 lux. The patient was given four color vision screening tests, including the Richmond HRR 4th edition, Ishihara 24-plate test, Dvorine book test, and an F2 plate test. The patient performed perfectly on all of these tests, with the exception of 1 miss on the Dvorine book test, which is still passing. The color-naming section of the Dvorine test was also administered, and the patient correctly named all saturated and desaturated colors.

The Farnsworth D15 was administered subsequent to the book tests, and the results are shown in Figures 1 and 2. There were ambiguous errors with only 1 major crossover over 2 trials that was along a red-green direction. By typical grading criteria, the patient passed the Farnsworth D15 test.

Anomaloscope testing was also performed. The test proved difficult for the patient, as she was unsure and sometimes inconsistent in her responses. Thus, the reliability of the anomaloscope for this patient was an issue. Keeping this issue in mind, a matching range of 43-55 was found for this patient, and the midpoint of this range was at the upper limit of the normative data collected for the instrument.

Finally, an FM100-hue test was performed, and the results are shown in Figure 3. The total error score of the patient was 372, and there were errors

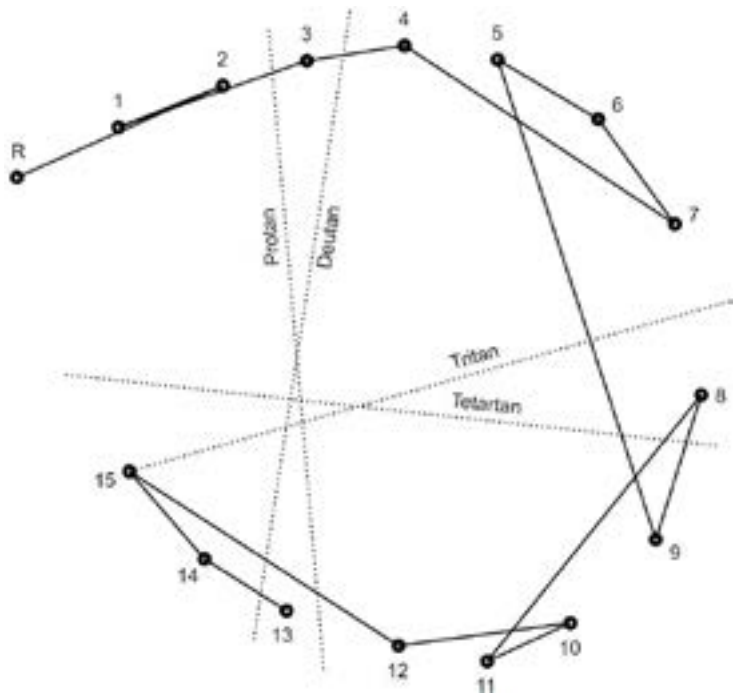

Figure 1. *Farnsworth D15 trial 1. One major crossover from cap 5 to 9 is seen, along with minor crossovers and transposition errors. Based on a common clinical outcome of 2 or more major crossovers as failing, the patient passed the test on this trial.*

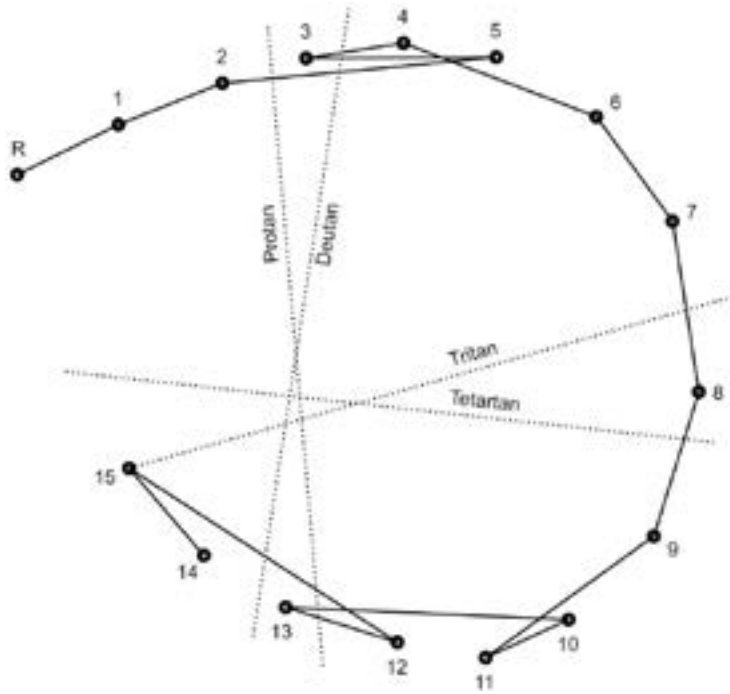

Figure 2. *Farnsworth D15 trial 2. A few minor crossovers, but no major crossovers, were evident on this trial. This would be a passing result using a criterion of 2 or more major crossovers as failing.*

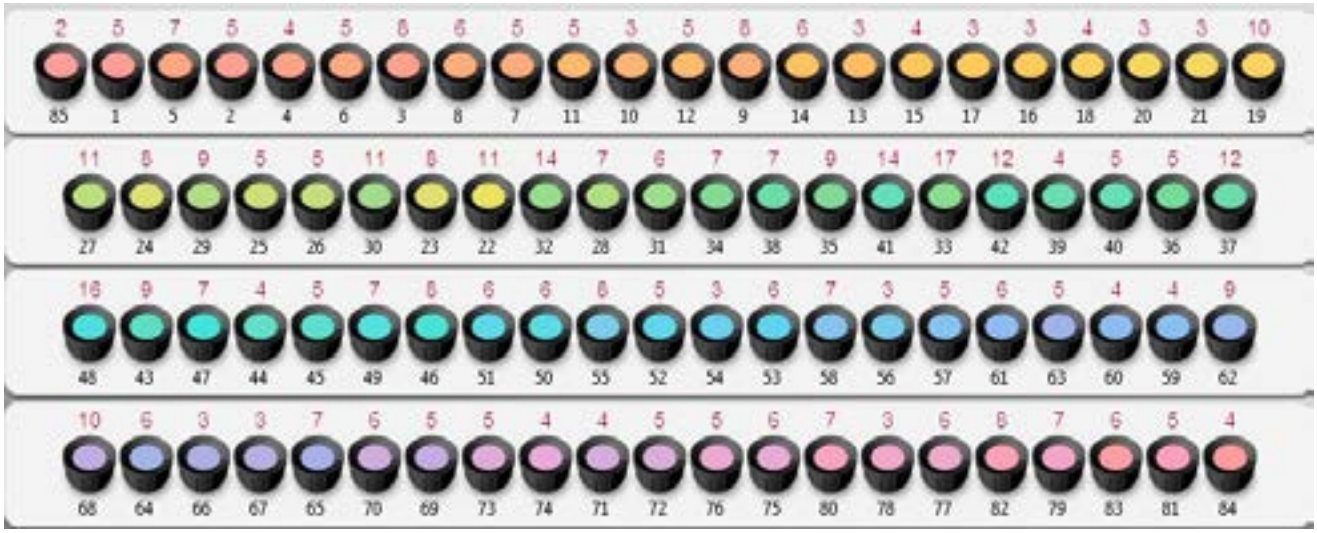

Figure 3. *FM100-hue test. The numbers below each cap indicate the designated cap number for that cap. The sequence is out of order in numerous places. The red numbers above each cap represent the cap error score, which is calculated as the sum of the cap differences between neighbors (e.g., Cap 2 has a cap error score of 5 because cap 5 on the left is 3 caps away and cap 4 on the right is 2 caps away, 3+2 = 5). Cap error scores greater than 2 would indicate an error. Nearly every cap error score was greater than 2. The higher the cap error score for a given cap, the larger the perceptual error.*

throughout the color circle. Based on normative data for 16-year-olds, the patient failed the test at the p=0.001 level, indicating that the likelihood of the patient performing so poorly on the test by random chance was extremely low and that the patient truly had a color vision issue. To pass the test statistically, the total error score would have to be below 135 based on one widely cited study and below 77 based on another study that focused on lower age groups.[10,11]

The patient and her mother, who was present during all of the testing, were counseled that she likely had genetically normal color vision but very poor color discrimination. Given that no acquired color deficiency was suspected based on normal systemic and ocular health and that no congenital deficiency was suspected based on testing, the patient was further counseled that she could likely improve her color aptitude with patience and practice. While the patient expressed some relief that the FM100-hue uncovered a color vision issue that correlated with her chief complaint, she also appeared anxious that she had a definite issue.

The patient was made aware that genetic color vision testing existed but was not readily available. The patient's mother was subsequently tested and was found to do perfectly on all color vision tests. The patient's father was unavailable for testing after repeated attempts to contact him.

Over time, the patient's mother was contacted again, and it was expressed that repeat anomaloscope or FM100-hue testing could be of value, as could trials of filters. However, while the patient's mother was fully encouraging of follow-up testing and management, she expressed that her daughter was generally withdrawn with regard to her color vision and did not want to discuss it any further.

Conclusion

This case report showed that even patients who do perfectly on a screening color vision book test may still have color vision issues that could be detected with additional tests. In particular in this case, the patient's chief complaint would have been inadequately addressed if only a screening book test had been administered. If the patient had a congenital color vision deficiency, even one mild enough to pass a screening book test, they would have had more definitive anomaloscope findings. On the anomaloscope, patients with very mild congenital color vision issues could have a small matching range, sometimes even smaller than in the present case, but the midpoint of such a range would be outside the normal limits. Additionally, the errors seen on the Farnsworth D15 and the FM100-hue test were not consistent with a congenital color vision deficiency. If the patient had an acquired color vision issue secondary to pathology or toxicity, the patient would have had a positive history of ocular pathology, which would likely include visual acuity or visual field defects, or a positive history of exposure to toxic chemicals. Given the very high total error score on the FM100-hue test, other macular deficiencies by subjective or objective testing would have been expected, but none were found at a recent comprehensive eye examination. If the patient ever

did return for follow-up, a macular OCT scan could be of value in this case.

Lastly, newer ways to investigate color vision issues and specific cone type dysfunctions, whether by subjective or objective means, could have been very beneficial in this patient's case. Genetic testing for color vision deficiency has been done in research labs but is not available to clinicians currently.[12] In fact, the genetics of congenital color deficiency is so well described that such knowledge has been used to cure color vision deficiency in animals.[13] Subjective and objective testing of color vision have also been able to measure the vision function of specific cone types, and this could have been of great value in this case.[14-16]

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