# Clinical validation of a computerized psychophysical test for color vision and contrast sensitivity

## *Validação clínica de teste psicofísico computadorizado para avaliação de visão de cores e sensibilidade ao contraste*

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**SUMMARY**

***Purpose:*** **To determine the reliability of TwoDocs computerized test for the evaluation of color vision and contrast sensitivity in normal adults.**

***Methods:*** **Thirty normal volunteers aged from 20 to 30 years (mean 23.3 years) had their color vision and contrast sensitivity tested by a new computerized test (TwoDocs test). Informed consent was obtained from all participants before testing. Inclusion criteria were: absence of visual complaints, absence of previous ophthalmic surgery, absence of family history of ophthalmologic diseases, best corrected visual acuity for near and distance of 20/20. Tests with the Farnsworth-Munsell 100-hue (FM-100) test for color vision assessment and the Pelli-Robson chart for contrast sensitivity measurement were also performed on the same visit, and both were considered gold standards for clinical validation.**

***Results:*** **The results of contrast sensitivity obtained with the Pelli-Robson chart and TwoDocs test showed agreement of 100%. Color vision results obtained with the TwoDocs test showed a strong trend to overestimate color vision classification when compared with FM-100.**

***Conclusion:*** **The new computerized psychophysical TwoDocs test showed a high sensitivity and specificity for contrast sensitivity measurement and can be a useful clinical tool in ophthalmology practice for this visual task. Color vision classification obtained with the TwoDocs test showed a low specificity when compared with FM-100. One possible reason for this overestimation is the computer monitor used to generate the color pattern. Additional studies in patients with disorders in color vision should be done for understanding the usefulness of this method better in clinical color vision assessment.**

**Keywords**: Color vision; Contrast sensitivity; Clinical assessment.

## INTRODUCTION

Assessment of visual functions plays an important role in ophthalmologic practice by helping in the diagnosis of ocular diseases, in their differential diagnoses, and in following their evolution as well as the efficacy of treatment [1].

Vision is a complex mechanism where visual acuity is an important but limited parameter; other important ones include color vision, contrast sensitivity, and visual field. Thus, some patients complain of decreased

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vision due to loss of contrast sensitivity that is not detected during conventional visual acuity assessment that does not vary the contrast of its optotypes [1-3]. Glaucoma, diabetic retinopathy, optic neuritis, multiple sclerosis, Alzheimer's disease, Parkinson's disease, and cystic fibrosis may be detected earlier by the application of tests for contrast sensitivity measurement[1].

Color vision assessment in ophthalmologic routine helps in the diagnosis of prereceptor lesions such as cataract, macular degeneration, pigment epithelium degeneration, and inflammatory or toxic maculopathies and vasculopathies; of receptor lesions such as cone degeneration (Stargardt's disease) or rod degeneration; and of postreceptor lesions such as optic neuritis, Leber's disease, optic atrophy, neuropathies of toxic drug origin, or glaucoma [4].

Some years ago, a computerized program, called the "TwoDocs Test" (version 95, TwoDocs Inc.), was created for the assessment of visual functions such as contrast sensitivity and color perception. It can be used for color vision and contrast sensitivity assessment in addition to assessing their alterations. According to the authors, the test consists of a group of programs able to present rapidly to the patient the different color and contrast variations as well as diagnosing their alterations. However, there are no reports in the literature on the clinical validation of this diagnostic instrument.

The purpose of the present study was to validate the TwoDocs test clinically in normal adult patients, comparing the results using as gold standards the Pelli-Robson chart for contrast sensitivity [2] and the Farnsworth-Munsell 100-hue test for color discrimination assessment. [5]

## METHODS

### *Participants*

Thirty normal volunteers (15 men and 15 women) with ages ranging from 20 to 30 years (mean = 23.9 ± 1.9) were assessed according to the following inclusion criteria: absence of visual complaints, absence of previous ophthalmic surgery, absence of family history of ophthalmologic diseases, best corrected visual acuity OU for near and distance of 20/20 as measured by Snellen's optotype chart, and refractive errors no greater than 3.00 SD (spherical equivalent). From each patient the eye with the better color discrimination, as obtained by the Farnsworth-Munsell test, was selected for the comparative study between the two methods for color vision assessment and the two methods for the determination of contrast sensitivity.

### *TwoDocs test*

The test consists of a group of programs supposedly able to present different color variations to the patient rapidly and, according to the responses, to classify his/her color discrimination. It also contains a program for the assessment of contrast sensitivity, as well as options for printing and scoring for the presentation of the results on the monitor or in printed material. The results may be stored in floppy disks or in the hard disk of the computer for future analyses and comparisons.

The program consists of:

1. A file to store patients' data;
2. Color gradations in order to assess alterations in color vision;
3. A test with 16 colors for the detection of losses in chromatic discrimination;
4. A test with 90 colors that assesses color vision losses over the whole color spectrum;
5. A Rayleigh anomaloscope for the diagnosis of variations in the red-green color vision;
6. A Moreland anomaloscope that identifies variations in the blue-yellow color vision;
7. A Whittenburg anomaloscope able to explore the red-blue spectrum;
8. A color test that identifies losses in the saturation and brightness within the color spectrum;
9. A test to determine contrast sensitivity using Gratings standards;
10. Contrast sensitivity and colored contrast sensitivity tests;
11. A program for the calibration of the monitor to ensure standardization during the application of the test.

In this study items 4 and 10 were applied with conventional contrast sensitivity, with optotypes.

### *Procedures*

The 90-hue test was used for the determination of color vision through the Color Test. This program consists of 5 rows containing 18 colored stones each, with the first and last being fixed. Each row is presented separately to the examined person, with its 16 central stones in a randomized order; the patient is instructed to arrange the stones so as to form an ordered sequence from the first to the last.

At the end of the ordering of the 5 color rows, the program shows the score and the printed results in the Farnsworth mode.

Color vision is classified according to the following categories:

Superior color discrimination: total error of 0 to 10;
Excellent color discrimination: total error of 11 to 25;
Medium color discrimination: total error of 26 to 100;
Poor color discrimination: total error >100.

Patients were seated comfortably in front of the computer monitor, previously calibrated through the Moncal program (Color Test), at a distance of 66 cm (approximately an extended arm) with the screen parallel to the face. The room was partially darkened but still allowed viewing of the keyboard and mouse.

OD was tested first, followed by OS. The patients were instructed to arrange the 5 color rows so as to form a

sequential order of colors. After finishing the ordering, the program provided printed color vision results in the Farnsworth mode. For comparison of the data obtained through the TwoDocs and Farnsworth tests, the classification of the Farnsworth-Munsell test was also adopted for the results obtained through the TwoDocs test.

### *Farnsworth-Munsell 100-hue test*

In this test, 85 black plastic stones with 12-mm diameter colored labels of varying chromatic values adhering to one side are grouped in 4 portions and separated in different boxes. The 1st box contains stones from pink to yellow (stones 85 to 22), the 2nd box from yellow to green (stones 21 to 43), the 3rd box from green to blue (stones 42 to 64), and the 4th box from blue to pink (stones 63 to 85). Each box contains fixed final and initial stones and 21 loose stones. The side of the stone opposite to the one with the label is numbered to allow the examiner to determine the patient's score.

In both tests the total number of errors made by the patient is determined by the sum of errors, minus 2, for each stone. Therefore, a perfect color sequence results in a total error equal to zero.

We adopted Farnsworth-Munsell color vision classification for:

Superior color discrimination: total error from 0 to 16 (16% of the population);
Medium color discrimination: total error from 17 to 100 (68% of the population);
Poor color discrimination: total error >100 (16% of the population).

During the assessment, 1 box of stones was presented once with the randomized stones on the table and the patient was asked to organize the colors within a specified time (2 minutes), so as to create a regular series between the fixed stones. The procedure was repeated with the other 3 boxes, always under adequate illumination[6]. All tests were performed monocularly, first for OD and then for OS.

The results obtained were drawn on a graph, according to the method proposed by Farnsworth through the FM test program (Gretag Macbeth). Color vision classification was based on the total errors, presented separately for either eye of the patient.

### *Pelli-Robson contrast sensitivity chart*

The chart consists of 48 optotypes in the form of letters of constant size, low spatial frequency, dark on a white background, organized as 16 trios of different contrasts. At each trio there is a 0.15 logarithmic unit reduction. The 1st trio presents 100% contrast (or 0.00 log) and that of the last trio is 0.56% (or 2.23 log). Eight trios are displayed on the left and 8 on the right of the table. The contrast threshold is determined by the last trio where at least 2 letters were correctly identified. The value of the minimum contrast threshold of the trio is printed at the side of the form. The normal range for individuals between 20 and 30 years of age is 1.65 to 1.89 log [2].

The participants were tested monocularly, 1st the right and 2nd the left eye, seated at 1 m from the chart, so that their eyes were directed toward its center, and using adequate illumination.

### *Measurement of contrast sensitivity by the TwoDocs color test*

The contrast sensitivity program, which randomizes the presentation of letters (H, U, E, C, L, F, or homogeneous pattern), was used for the determination of contrast sensitivity through the TwoDocs test. The test begins with the presentation of one of the black letters (maximum contrast), and the next letters are presented with a gradual decrease in contrast. The patient is asked to answer by identifying the presented letter. If none of the letters has been identified, the key corresponding to the homogeneous pattern is selected. After performing the test with OD and OS, the program provides the patient's contrast sensitivity loss, expressed as normal, medium, moderate, or severe.

The patients were comfortably seated in front of the computer monitor, previously calibrated through the Moncal program, at a distance of 66 cm (approximately an extended arm) and with the screen parallel to the face. The room was darkened but still allowed viewing of the keyboard and mouse. The program presented the letters (H, U, E, C, L, F) or nothing (homogeneous pattern) on its screen, with a specified duration, and the subject informed the examiner if there was any letter on the screen and identified, when possible, the presented letter. We adopted the option "Speckled," which randomizes the variation of contrast presentation. At the end of the test, the program provided the results of contrast sensitivity loss numerically for OD and OS as normal, medium, moderate, or severe.

## RESULTS

The results obtained by the TwoDocs test were converted according to the Farnsworth classification, following the total of presented errors. Table 1 shows the results.

Contrast sensitivity results obtained through the Pelli-Robson chart were classified into normal and abnormal.

Agreement between the results of both tests was 100%, considering classification by categories (Table 2).

## DISCUSSION

New tests for the assessment of visual functions are continually being developed and introduced in clinical ophthalmology. The decreasing cost and advances in electronic technology will make the computerization process for the color vision test easy. Color computers may prove as useful for testing color vision function as computerized perimetry for glaucoma [7].

In order to be considered efficient as a clinical assessment,

**Table 1. Color vision results**

| | Superior error from 0 to 16 | Medium error from 17 to 100 | Low error >100 | Total |
|---|---|---|---|---|
| Farnsworth | 12 - (40.0%) | 17 - (56.6%) | 1 - (3.3%) | 30 |
| TwoDocs | 25 - (83.3%) | 5 - (16.6%) | 0 - (0.0%) | 30 |
| Total | 37 | 22 | 1 | 60 |

a new test should assess the sensory properties of vision, provide *high sensitivity* and *specificity* in order to distinguish sudden abnormalities from normal responses, show high quality and reproducibility and easy management and interpretation, and, above all, offer advantages over preexisting test procedures.

The test used in this study (TwoDocs) showed complete agreement with the contrast sensitivity results obtained by the Pelli-Robson chart for normal patients. However, it should be emphasized that the contrast sensitivity assessment of this study only classified this visual function into normal or abnormal. In order to understand the clinical usefulness better, further studies are required, assessing contrast sensitivity losses in low, medium, and high frequencies.

The results of the tests for the determination of color vision did not agree. The responses to TwoDocs may be considered to be overestimated. It overestimated superior color vision by 2.08 times, medium color vision by 3.4 times, and was not sufficiently sensitive to detect low color vision as does the Farnsworth-Munsell test.

During the application of the tests, all patients reported easier ordering of the colors in TwoDocs, but this test was not able to present the same chromatic variations as the Farnsworth test in spite of the high quality of the calibrated monitor and color cards used in the computer. At this time, the equipment is not able to reproduce the colors of the gold standard faithfully, thus overestimating the diagnosis. The same was reported for the computerized color vision test City University Colour Vision Test (CUT) [7].

In conclusion, the TwoDocs test is reliable in the case of contrast sensitivity assessment in normal patients. In addition, because of its prompt application and interpretation, it can be used in routine ophthalmologic screening for the determination of color vision in these patients, and their diagnosis can be confirmed with conventional methods such as the Farnsworth-Munsell test.

Further studies should be carried out for the determination of TwoDocs sensitivity in the diagnosis of color vision, for instance, performing studies on patients with previously diagnosed alterations in this visual function.

**Table 2. Contrast sensitivity results**

| | Normal | Anormal | Total |
|---|---|---|---|
| Pelli-Robson | 30 - (100.0%) | 0 - (0.0%) | 30 |
| TwoDocs | 30 - (100.0%) | 0 - (0.0%) | 30 |
| Total | 60 | 0 | |


## RESUMO

Objetivo: *Avaliar a confiabilidade do teste computadorizado TwoDocs para a determinação da visão de cores e sensibilidade ao contraste em indivíduos adultos normais.*
Métodos: *Trinta voluntários normais, com idades variando de 20 a 30 anos (média de 23,3 anos) foram submetidos ao TwoDocs Test para determinação de sua sensibilidade ao contraste e classificação de sua visão de cores. Seus resultados foram comparados com os dados obtidos pelas tabelas de Pelli-Robson e Farnsworth-Munsell 100 cores.*
Resultados: *O teste TwoDocs mostrou total concordância com os resultados da sensibilidade ao contraste obtidos com a tabela de Pelli-Robson. Os testes para determinação da visão de cores não concordaram em seus resultados pois a avaliação dessa função visual por meio do teste TwoDocs foi superestimada tendo como base os resultados apresentados pelo teste Farnsworth-Munsell.*
Conclusão: *Concluiu-se que o TwoDocs é um método confiável para a determinação da sensibilidade ao contraste em pacientes normais entre 20 e 30 anos de idade. Na avaliação clínica da visão de cores, os resultados obtidos com o teste computadorizado TwoDocs devem ser criteriosamente analisados, tendo em vista a superestimação da classificação da visão de cores. Estudos adicionais em pacientes com defeitos na visão de cores são importantes para melhor compreensão da utilidade clínica do método.*


***Palavras-chave**: Visão de Cores; Sensibilidade ao contraste; Avaliação clínica.*

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