

## UNUSUAL PREVALENCE OF COLOR VISION DEFECTS IN CHILDREN FROM A SMALL BULGARIAN TOWN

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Мила Драгомирова, Снежана Йорданова. НЕОБИЧАЙНО ВИСОКО РАЗПРОСТРАНЕНИЕ НА НАРУШЕНИЯ В ЦВЕТНОТО ЗРЕНИЕ ПРИ ДЕЦА ОТ МАЛЪК БЪЛГАРСКИ ГРАД

Цветното възприятие, като една от важните характеристики на зрението, е изследвано по време на скрийнинг на 203 ученици на възраст между 6 и 18 години, живеещи в Сапарева баня. Изследването е проведено чрез псевдоизохроматични карти на Ишихара, тест на Farnsworth D-15 и тест на Lanthony Desaturated D-15. С оглед спестяване на време тестовете са проведени бинокулярно. Според картите на Ишихара измежду 87 момчета и 116 момичета 9.2% и 4.31% съответно имат наследствен цветови дефицит. Даните от статистическата обработка са сравнени с други известни от целия свят. Нито един от изследваните ученици по-рано не е изследван за цветно възприятие. Измежду тях са открити случаи с проблеми в цветното възприятие, които не са разпознати нито от ученика, нито от родителя, нито от учителя.

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Color perception as one of the important attribute of vision is investigated during the screening session of 203 school students between 6 and 18 years old, from a small town Sapareva Banya. The examination was performed through Ishihara pseudoisochromatic plates, Farnsworth D-15 test and Lanthony Desaturated D-15 test. In the interest of saving time during

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the screening the tests have been administered binocularly. According to Ishihara plates among the 87 boys and 116 girls, 9.2% and 4.31% had a congenital color defect, respectively. The statistically processed data from color vision tests have been compared with other known data from all over the world.

All students have never been tested for color perception. Among them there were found cases with lack of student, parental, and teacher recognition of presence of color perception problems.

**Keywords:** *anomalous* color vision, pseudoisochromatic plates, arrangement test, Ishihara, Farnsworth D-15, Lanthony Desaturated D-15, school students screening.

**PACS numbers:** 42.66.Ne

## 1. INTRODUCTION

Color vision, in particular in humans, is the ability to distinguish objects based on the wavelengths of the light they reflect, emit, or transmit. The light level is also important prerequisite to see the color. Normal human color vision, in daylight is trichromatic, based on the presence of three spectrally-distinct types of cone photoreceptors – red, green and blue. Their response to light in the retina depends on the wavelength of peak absorption for the different cone pigments (i.e. 560, 530 and 420 nm). When there is an alteration or absence of one of the receptor photopigments the person is characterized with a color vision deficiency (CVD). The latter could be congenital/inherited CVD or acquired. The first type CVD is nonpathological, incurable and it does not change over time. The most common is the red-green deficiency, which is inherited as an X-chromosome-linked recessive trait. Acquired color deficiency accompanies another condition (e.g. disease, trauma) or it is caused by the side effects of certain drugs, medications or exposure to chemical toxins. Acquired color deficiencies are classified as red-green and blue-yellow [1].

The people with inherited CVDs are classified as anomalous trichromats, dichromats, and monochromats. The anomalous trichromat is a relatively mild form of defective color vision. The terms protanomaly, deuteranomaly and tritanomaly are given when there is a defect in red, green and blue pigments, respectively. The dichromats base their color vision on only two pigments. The class of dichromats characterized by entire absence of green cones, red cones or blue cones is called deuteranopia, protanopia and tritanopia, respectively. Protanomaly and protanopia are referred to protan CVD whereas deuteranomaly and deuteranopia to deutan deficiency. Protan and deutan CVD are often described as red-green deficiency. Tritanomaly and tritanopia are described as the tritan or blue-yellow CVDs.

The lack of systematic early age color vision examination in Bulgaria suggests a large number of people affected by CVD to remain undetected as they simply adapt to the environment to certain extent and also because of unawareness of the disorder. Because of the role color coding plays in instructional materials used during the early school years, the color-deficient student may find some tasks difficult and, as a con-

sequence, may develop a dislike for school and learning. Which in turn hinders the development of the pupil's potential. The student color vision status is also important when choosing a future profession. Currently, there is no treatment for congenital CVD, however the sooner the color vision deficiency can be identified the sooner accommodation can be made to help the child. Considering these aspects, there is an increasing interest across the world [2–6] in view of identifying the prevalence of color vision deficiencies in school children. The study aims to explore these deficiencies in school age children in the small Bulgarian town Sapareva Banya. During the screening session in case of color vision deficiency the parents of the child were informed so that it can be guided properly in his learning process as well as in choosing and adjusting with the suitable profession.

## 2. METHODES AND MATERIALS

### 2.1. PARTICIPANTS

The screening session of school students from Sapareva Banya took place in January 2017. A total of 203 students aged 6–18 years (both males and females) were evaluated for congenital color vision deficiency. The students were selected by purposive sampling method. Only these interested and intending to be evaluated were enrolled in the present study. Investigation of visual acuity preceded color testing.

### 2.2. STIMULI AND PROCEDURE

The screening of all students was done by using Ishihara 38 Plates Edition as according to instruction in the case of large scale examination the test was simplified to an examination of six plates only (№ 1, one of № 2–5 one of the № 6–9 one of № 10–13 one of № 14–17 and one of № 18–21). In the assessment of color appreciation by this short method involving 6 plates only if there was a discrepancy in any of the recordings, a number of plates was used before diagnosing deficiency. The plates were held about 75 cm from the child and tiled so that the plane of paper is at right angle to the line of vision. Time allowed to each plate did not exceed 5 seconds. In the case of subject unable to read numerals, plates 18–24 are used and the winding lines between the two X's are traced with a brush within ten seconds. While the Ishihara's test is designed to assess color vision deficiency of congenital origin the two other used tests Farnsworth D-15 and Lanthony Desaturated D-15, which are arrangement test, in addition give opportunity to diagnose acquired color vision deficiency. Manifestation of the latter is not expected in the studied group but as it is known [6] the color perception in blue-yellow region is changing due to both cognitive development and development of the color vision system. The Farnsworth D-15 test is called "dichotomous" [7] because it was designed to sep-

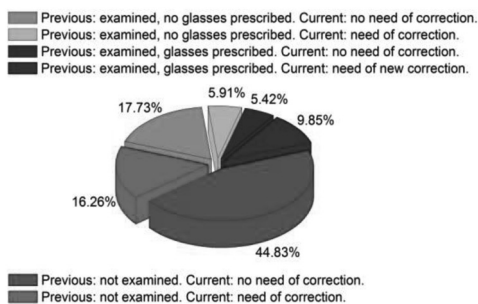
arate subjects into one of two groups: 1) strongly/medium color deficient or 2) mildly color deficient or color normal. The Lanthony D-15 test was designed also to separate patients into one of two groups: 1) mild color deficient or 2) normal color perception. The only difference between these items is the color saturation of the discs. According to the identical administration needs of both arrangement tests they were carried out on a black background to prevent surroundings from affecting the color perception by the students.

*The tests were conducted at a working distance (25–30 cm) in about 2 minutes. The arrangement tests procedure stated with explanation of the task, according to [1]: "Find a cap from here (indicate the random array of the 15 moveable caps) that looks most like this cap (indicate the reference or pilot cap), and place it next to the fixed cap in the tray. Then find the cap that looks most like the one you already selected, and repeat this until you have placed all of the caps in the tray". Although the researcher checked after instruction that the participant understood the task condition the results of 5 from 150 and 3 of 94 examined students are removed from the Farnsworth D15 and Lanthony D15 analysis, respectively, because they imply poor task comprehension.*

The tests administration was organized in a bright room without direct sunlight. In the interest of saving time during the screening all color tests were administered binocularly. The students have been wearing their refractive correction in case of proven need, and there was no tint in the glasses or contact lenses.

### 3. RESULTS AND DISCUSSION

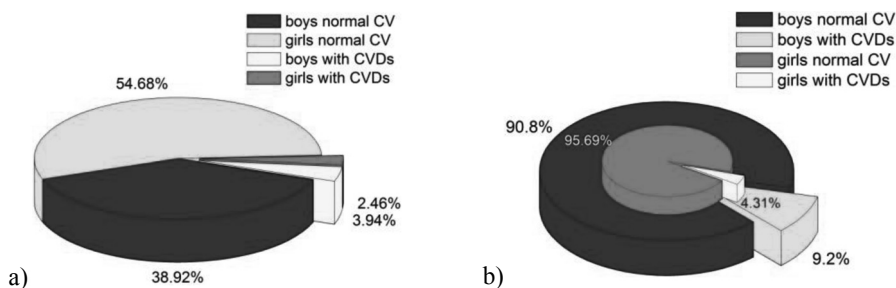
In this study 203 students (boys 87, girls 116) are examined. The screening session started with a questionnaire comprising the following information about students: have they had some eye examination and do they have any prescribed glasses. The initial study of students' visual acuity divided them generally in two groups (Fig. 1). The first one contains 124 students, who have never been to an eye specialist. The results of the current screening showed that 91 of them (44.83%) still do not need glasses, while the other 33 (16.26%) were asked to visit an eye specialist for additional examination for prescription of glasses. The second group includes 79 students, who have been to an eye examination. From them, 48 in number did not need eye correction, while the other 31 needed corrections and carry glasses. The present visual acuity tests revealed that among the students who have attended before an eye specialist, 12 (5.91%) students without glasses need a correction and 20 (9.85%) students with glasses needed a new correction.



**Fig. 1.** Results from previous eye examinations of children from Sapareva Banya, compared with the current screening

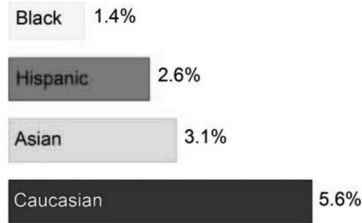
### 3.1. ISHIHARA TEST

The subsequent study of color vision of the students, by Ishihara test, revealed that out of total 203 students, 13 (6.4%) were color deficient (Fig. 2a), according to Ishihara test plates. From them, 8 are boys and the other 5 are girls. The statistical treatment of gender-related outcomes (Fig. 2b) showed that among 87 boys and 116 girls, 8 (9.2%) and 5 (4.31%) were color deficient, respectively.



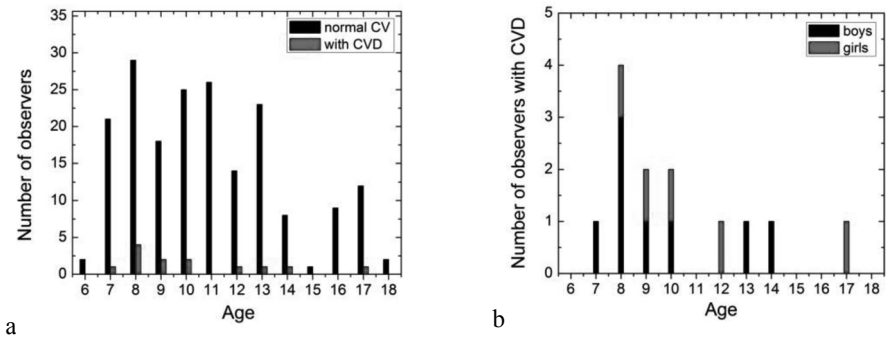
**Fig. 2.** Distribution of girls and boys with normal color vision (CV) and with color vision deficiency in (a) and gender-related percentages in (b)

According to the world statistic [8–10] about 8% of all men and about 0.5% of all women are suffering from congenital CVD. The variability of the latter depends also of the ethnic group. The higher prevalence in male population of CVDs provided the information given in Figure 3. In-depth review of the literature, however, shows that authors report for both higher male Asian (11.05%) [5] and female (0.83%) [4], (2.42%) [5] CVDs. However, no data for such extremely high prevalence of CVD in female population as this established in Sapareva Banya are reported.



**Fig. 3.** Prevalence of color vision deficiency in boys, by ethnicity [4]

The distribution of number of students with normal color vision and with CVD on age is shown in Figure 4a. Higher number of students with CVDs was established in the most numerous age groups of the 8 year olds. The latter consisted of 3 boys and 1 girl (Fig. 4b) with CVDs. In the groups of 9 and 10 year olds the number of boys and girls with CVD was the same. According to world data for gender-related prevalence of CVD the existence of age groups with only male representatives is not surprising. This is not the case, however of the age groups (see Fig. 4b), 12 and 17 year olds with only female representatives with CVD. The most likely cause was that in these groups the number of boys was 6 and 2 in 12 and 17 year olds, respectively.



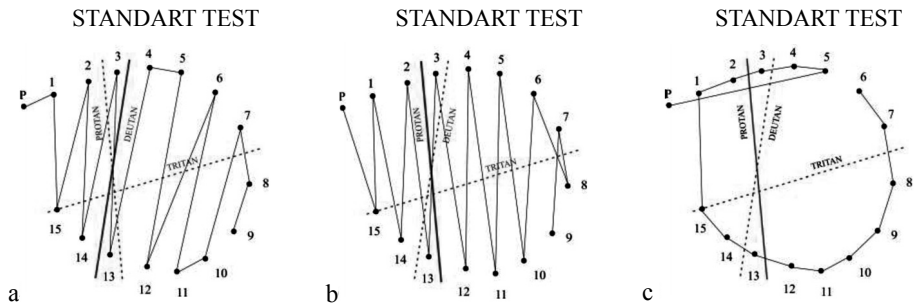
**Fig. 4.** Distribution of the students with normal color vision and with CVD on age in (a) and gender-related number of students in (b)

### 3.2. FARNSWORTH D-15 TEST

**Table 1.** Comparison between Ishihara and Farnsworth D-15 tests for color vision deficiency. Values are number of students

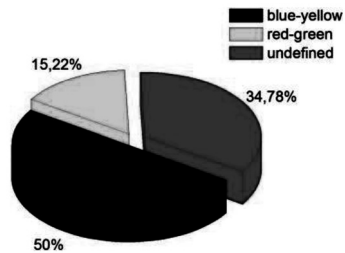
Color Test		Pass Ishihara	Fail Ishihara	Total
Pass D15		86	4	90
Fail D15	red-green	7	7	14
	blue-yellow	23	0	
	undefined	16	2	
Total		132	13	145

The color vision of 145 students out of 203, surveyed with the Ishihara test, was investigated in addition with the Farnsworth D-15 test. The results of both color vision tests were summarized in Table 1. Out of all 13 students who failed the Ishihara test, 7 failed also on Farnsworth D-15, but 4 successfully passed D-15 and another 2 have made mistakes on D-15 which did not allow determining accurately the CVD. Illustrations of some of the students' results with red-green CVD according to Ishihara and Farnsworth D-15 tests are shown on Figure 5. Typical distribution of caps arrangement of deutan (Fig. 5a) and protan (Fig. 5b) CVD was established in two of boys examined. The result of D-15, shown on Fig. 5c, reveals protanomalous CVD of a girl.

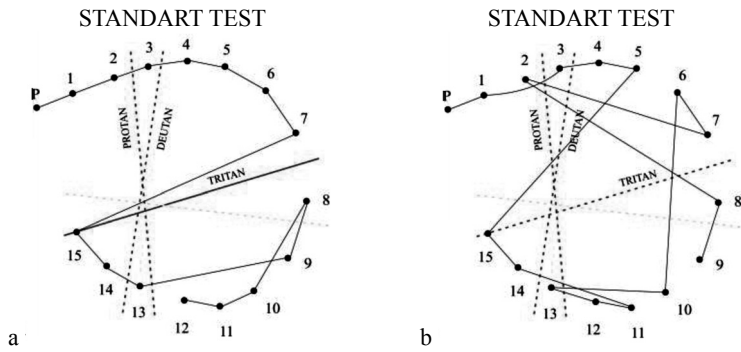


**Fig. 5.** Examples of Farnsworth D-15 test arrangements in the case of deutan (a), protan (b), and protanomalous (c) CVD

Among those who passed successfully Ishihara test plates, 132 in number, 86 passed also D-15 but the other 46 failed on it. The distribution of CVDs between them is shown on Figure 6. Another 7 (5.22%) students had red-green CVD, 23 (50%) – blue-yellow CVD (Fig. 7a) and 16 (34.78%) in number, have made mistakes on D-15 which did not allow determining accurately the CVD (Fig. 7b).



**Fig. 6.** Distribution of the students with color vision deficiencies who failed Farnsworth D-15 test but passed successfully Ishihara test plates



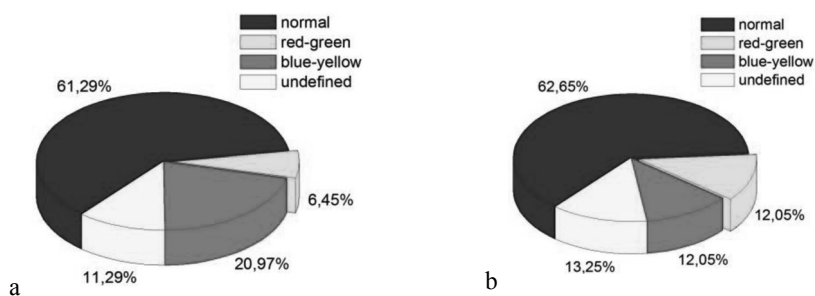
**Fig. 7.** Examples of Farnsworth D-15 test arrangements in the case of blue (a), and undefined (b) CVD

According to Ishihara test (Table 2) 8 boys were with red-green CVD, 4 of them have shown results on D-15 that confirm this CVD, 1 was classified with undefined CVD and another 3 – as such with normal color vision with respect to D-15. The situation in girls was quite different. 5 girls were selected as such with red-green CVD according to Ishihara, 3 of them also failed on D-15, 1 was classified with undefined CVD and another girl passed without any problems D-15. The results of D-15 showed, however, that among those girls who successfully passed Ishihara, 7 failed on it. So, according to Farnsworth D-15 test (Fig. 8) among 62 boys and 83 girls, 4 (6.45%) and 10 (12.05%) were with red-green color vision deficient, respectively. The results of D-15 revealed an extremely high prevalence of red-green CVD in the young female population in Sapareva Banya which even exceeded the world male trend. Age distribution of red-green CVD in young male and female population according to Farnsworth D-15 is given in Figure 9. The results revealed also that the blue-yellow CVDs exceed those of red-green deficiencies. The distribution of the students with those CVDs on age could be traced out in Table 3.

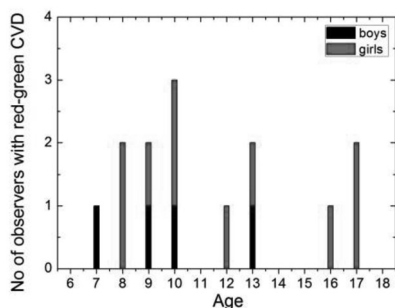
**Table 2.** Comparison between gender-related color vision deficiencies from Ishihara and Farnsworth D-15 tests. Values are number of students

Color Test		Boys Ishihara		Girls Ishihara		Total
		Pass	Fail	Pass	Fail	
Pass D15		0	3	0	1	4
Fail D15	red-green	0	4	7	3	14
	blue-yellow	0	0	0	0	0
	undefined	0	1	0	1	2
Total		8		12		20





**Fig. 8.** Distribution of boys (a) and girls (b) with normal color vision and with color vision deficiency according to D-15



**Fig. 9.** Age distribution of the examined boys and girls with CVDs according to Farnsworth D-15 test

**Table 3.** Distribution of color vision deficiencies on age according to Farnsworth D-15 test

Age	Red-green		Blue-yellow		Undefined	
	Boys	Girls	Boys	Girls	Boys	Girls
7	1	-	1	-	-	-
8	-	2	5	3	2	2
9	1	1	4	1	-	2
10	1	2	1	2	3	2
11	-	-	-	1	1	1
12	-	1	1	-	1	-
13	1	1	1	-	-	2
14	-	-	-	1	-	1
16	-	1	-	-	-	-
17	-	2	-	2	-	1
Total	14		23		18	

### 3.3. LANTHONY DESATURATED D-15 TEST

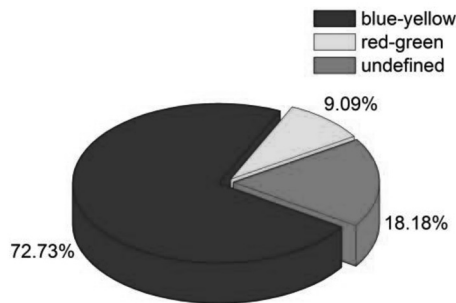
The color vision of 91 students out of 203, surveyed with the Ishihara test, was investigated also with the Lanthony Desaturated D-15 test. The results of both color

vision tests are summarized in Table 4. Out of 5 students who failed the Ishihara test, 2 failed also on Lanthony Desaturated (LD) D-15, 2 successfully passed LD D-15 and another 1 made blue-yellow mistakes on LD D-15.

**Table 4.** Comparison between Ishihara and Lanthony Desaturated D-15 tests for color vision deficiency. Values are number of students

Color Test		Pass Ishihara	Fail Ishihara	Total
Pass LD D15		42	2	44
Fail LD D15	red-green	4	2	47
	blue-yellow	32	1	
	undefined	8	0	
Total		86	5	91

Among those who passed successfully Ishihara test plates, 86 in number, 42 passed also LD D-15 but the other 44 failed on it. The distribution of CVDs between them is shown on Figure 10. Another 4 (9.09%) students had red-green CVD, 32 (72.73%) – blue-yellow CVD and 8 (18.18%) in number, have made mistakes on LD D-15 which did not allow determining accurately the CVD.



**Fig. 10.** Distribution of the students with color vision deficiencies who failed Lanthony Desaturated D-15 test but passed successfully Ishihara test plates

**Table 5.** Comparison between Farnsworth D-15 and Lanthony Desaturated D-15 tests for color vision deficiency. Values are number of students

Color Test	Pass D15	Fail D15			Total
		red-green	blue-yellow	undefined	
Pass LD D15	22	1	1	0	24
Fail LD D15	red-green	0	6	0	42
	blue-yellow	20	0	3	
	undefined	5	0	2	
Total	47	19			66

The results of 66 students, to whom both arrangement tests Farnsworth D-15 and Lanthony Desaturated D-15 were performed, are summarized in Table 5. It is important to note that from the 6 students diagnosed with red-green CVD according to D-15 and LD D-15 only 2 of them failed on Ishihara. The other 4 students were part of those (7 in number, see Table 2) which failed on D-15 and have been checked with both arrangement tests. They were all girls. The confirmation of results from two independent color tests for more girls with red-green CVD than those defined according to Ishihara test plates showed that the prevalence of red-green CVD in young female population in Sapareva Banya is at least as much as this indicated from Ishihara test. The results in Table 5 reveal that among those students who passed successfully D-15 almost half of them have shown on LD D-15 the presence of milder blue-yellow CVD. This could be traced out and from the results in Table 1 (D-15) and Table 4 (LD D-15), where 23(15.86%) students of 145 and 33(36.26%) students of 91, respectively, have shown blue-yellow CVDs. The changes in blue-yellow perception on the one hand are associated with acquired CVD due to some systematic or ocular disease, toxicity, or trauma on the other hand are associated with the immature visual system of tested students which have none of the reported symptoms. The trend in the development of the color vision system suggests fewer students with stronger blue-yellow CVD compared to those with milder CVD. This expectation is also confirmed by the research, 15.86% with more pronounced CVD in blue-yellow region versus 36.26% with less pronounced CVD in the same region. According to results from LD D-15 the blue-yellow CVDs exceed those of red-green deficiencies. The distribution of the students with those CVDs on age could be traced out in Table 6. The precise evaluation of CVD distributions over ages needs additional statistical data.

**Table 6.** Distribution of color vision deficiencies on age according to Lanthony Desaturated D-15 test

Age	Red-green		Blue-yellow		Undefined	
	Boys	Girls	Boys	Girls	Boys	Girls
8	-	-	-	1	-	-
9	-	1	-	1	1	-
10	-	-	-	2	-	1
11	-	-	4	1	-	1
12	-	1	1	4	1	1
13	-	1	6	4	1	-
14	-	-	-	3	1	-
16	-	1	-	2	-	-
17	-	2	-	3	-	1
18	-	-	-	1	-	-
Total	6		33		8	

Most of the students with established during the screening session CVD had not previously recognized its presence. This is somewhat understandable as they were born with it. It was surprising, however, that parents who accompanied their children were really surprised to find out that their child had a color vision deficiency even if it was from the strongest red-green type – deutan and protan (see Figs. 5a,b).

#### 4. CONCLUSIONS

In the beginning of 2017, the first of its kind screening session of the color vision of students from a small Bulgarian town was held. The color perception of 203 school students between 6–18 years old was examined through three color tests: Ishihara pseudoisochromatic plates, Farnsworth D-15 test and Lanthony Desaturated D-15 test. According to Ishihara plates among the 87 boys and 116 girls, 8 (9.2%) and 5 (4.31%) had a red-green color vision deficiency, respectively. The world statistic reported about 8% of all men and about 0.5% of all women are suffering from congenital red-green color vision deficiency as the variability of the latter depends also of the ethnic group. The established male percentage in the study correlated with the well-known data, however the extremely high percentage in female population exceeded even the highest found (2.42%) in the literature [5]. According to Farnsworth D-15 test among 62 boys and 83 girls, 4 (6.45%) and 10 (12.05%) were found to have red-green color vision deficient, respectively. The results of D-15 for the girls' problems in color perception even exceeded the world male trend. A part of the girls with CVD established from D-15 girls was tested with the Lanthony Desaturated D-15 test which confirmed the result of D-15. The studies done revealed that the prevalence of the red-green color vision deficiency in female population in Sapareva Banya is not lower than that established by the Ishihara test plates.

The observed high prevalence in the blue-yellow perception deficiency will be subject of further study. At least partially it may be explained by the fact that at school age the cognitive abilities and color vision system are still forming.

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