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Polychromatism of all light waves: new approach to the analysis of the physical and perceptive color aspects

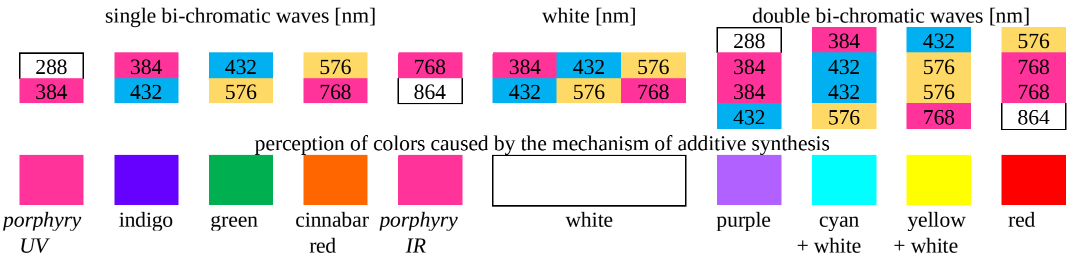
Justyna Niewiadomska-Kaplar

tab edizioni
Viale Manzoni 24c
00185, Rome, Italy

micromacro@ymail.com

ABSTRACT

Research on light vision mechanisms in biosystems and on the mechanisms of formation of deficits in color discrimination [Nie20a] reveals that not only white light is polychromatic but all light waves are. The spectrum of white light is composed of aggregations of only 4 monochromatic waves: *magenta UV*[1] 384 nm, cyan 432 nm, yellow 576 nm and *magenta IR* 768 nm, grouped in 5 **bi-chromatic** waves: cinnabar red (*magenta IR* + yellow), green (yellow + cyan), indigo (cyan + *magenta UV*) and also two *semi-bright* bi-chromatic waves - *porphyry IR* (semi-infrared wave composed of the *magenta IR* 768 nm wave and the colorless infrared wave 864 nm) and *porphyry UV* (semi-ultraviolet wave composed of the *magenta UV* 384 nm wave and the colorless ultraviolet wave 288 nm). The light waves thus composed create the light sensations due to the mechanism of additive synthesis.



The method allows a new approach to interpret the composition of the bright waves, the phenomenon of decomposition of colours and additive synthesis that constitutes the principle of colour production in computers. The new elaborate models of colour physics also constitute the basis by interpretation of the mechanisms of vision of colours.

Keywords

Human photoreceptors (cones) are sensitive to: cyan 432 nm, yellow 576 nm and cyan + yellow = green 504nm, Bright waves consist of aggregation in couples of heterogeneous 4 monochromatic waves: 384 nm, 432nm, 576 nm and 768nm.

1. INTRODUCTION

This research is based on two beliefs regarding the collecting and processing of data on acoustic waves (distinction of the height of sound) and electromagnetic waves of the visible (distinction of colors):

1/ The human brain is a "digital" and non -analogical tool, therefore it produces information on the acoustics and electromagnetic waves through the codification of the information and not through the measurement of all acoustic waves of the audible and all electromagnetic waves of the visible;

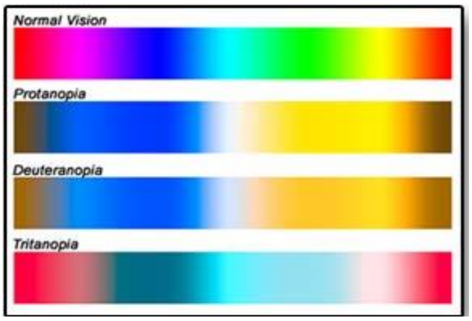
2/ The instruments of measurement of the wave motion such as cochlea or photoreceptors must be considered as biosensors who work as precise and objective instruments of measurement of these parameters of the wave motion for which they have

[1] The denomination of the waves that have wavelengths 384 and 768 nm as *magenta UV* or *IR* and of the couple of the waves that have wavelengths 384/288 nm and 768/864 nm as *porphyry UV* or *IR* is proposed from the author.

evolved in the space of millions of years, which therefore in their context of sensitivity they are equal at the measurement tools created artificially.

The starting point of the reasoning on the polychromatism of all light radiation has become analysis of the polychromatic composition of the light waves perceived such as red, green and blue revealed by the deficit in the distinction of colors. For this reason, the following table is proposed that illustrates some of these deficits and the citation of how they are explained in literature.

"Protanopia and deuteranopia are various forms of red-green colorblindness, the most common form of dichromia (protanopia is a deficiency in red cells, deuteranopia a deficiency in green; the results are similar because red and green are close in wavelength). Tritanopia is commonly called blue-yellow colorblindness and is less common, with full colorblindness (monochromia) being very rare." [AVI22a]



Author proposes the following questions to readers:

- Why cyan is seen as white by the Protanopes and Deuteranopes?
- Why both green and yellow are seen as yellow by the protanopes and deuteranopes?
- Why is yellow seen as white by the Tritanopes?
- Why both cyan and green are seen cyan by the Tritanopes?

The answer to these questions proposed by the author reveals the polychromatism of the bright waves that we perceive as red, green and blue.

2. STATE OF ART

The proposed research verifies the following three postulates of the theories on the vision of color and on the nature of the bright radiation in which it is stated that:

1/ White light only is polychromatic: the visible light waves are countless monochromatic waves between 380-760 nm; [Enc08a]

2/ Human photoreceptors responsible for the distinction of colors (cones) are sensitive to red, green and indigo (RGB); [Enc08a]

3/ Deficit of the discrimination between the colors are due to non-phototransduction by the cones of one of the RGB signals. [Cro01a]

3. DESCRIPTION OF THEORY AND EXPERIMENTS

3.1. The fluctuation of the speed of light hypothesized, selects only 4 monochromatic waves as part of the visible: 764 nm, 576 nm, 432 nm and 384 nm

Based on the considerations on the fluctuation of the speed of the propagation of the wave motion [Nie18a] it is deduced that the spectrum of the visible is discontinuous because the frequencies of the visible are only four.

432 THz	576 THz	768 THz	864 THz
(768 nm)	(576 nm)	(432 nm)	(384 nm)
magenta IR	**yellow**	**cyan**	***magenta UV***

These four frequencies are interpreted by the brain like magenta, yellow and cyan and with these three chromatic sensations (plus black and white) the brain builds all colors through the following mechanisms:

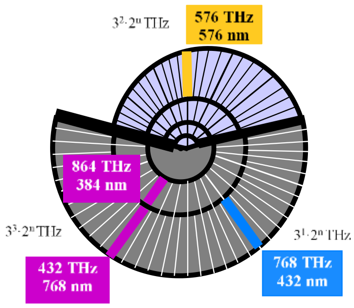
- homologation of frequency multiples,
- additive synthesis,
- on-off phototransduction system of the cones signals that produces 6 chromatic and 2 achromatic information.

3.2. The luminous frequency multiple (384 - 768 nm) is considered homologous, as is the case for the perception of height of the sounds

The four bright waves are perceived as three fundamental colors: **cyan** 432 nm, **yellow** 576 nm and ***magenta UV*** 384 nm and ***magenta IR*** 768 nm: 768 nm being the multiple of 384 nm is perceived as the same color.

In the perceptive systems that concern the distinction of the parameters of the wave motion, the multiples of frequency are considered homologous. At the perceptive system of the sound the multiples of frequency (the octaves) also calling them with the same name. For example, sounds with 32, 64, 128, 256, 512 Hz are all called Do. By analogy in this research, the bright wave of 384 nm, like the luminous wave of double length, equal 768nm, is distinguished as the magenta.

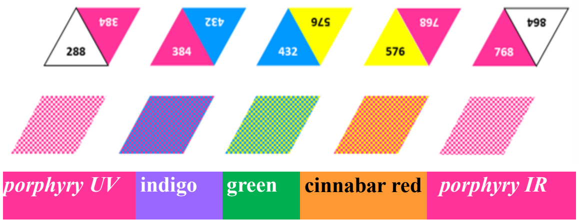
The logarithmic spiral in which the volutes divide the values of the frequency multiples placed on the radial axes is the model proposed in this research work to represent the increase in energy generated by the frequency of the wave motion. (Note the resemblance of structure of the cochlea.) [Nie18a]



magenta IR	yellow	cyan	*magenta UV*
432 THz	576 THz	768 THz	864 THz
768 nm	576 nm	432 nm	384 nm

3.3. The luminous wave consists of two heterogeneous monochromatic waves

According to this thesis with the four monochromatic waves - **cyan** 432 nm, yellow 576 nm, ***magenta UV*** 384 nm and ***magenta IR*** 768 nm - three bi-chromatic bright waves are formed: **cinnabar red**, **green** and **indigo**. In addition, the perceptual system is able to recognize the magenta components in the infrared and ultraviolet waves, present at the two extremes of the visible. To be part of the rose of the visible waves, two half-visible waves also enter for this reason: *porphyry IR* (semi-infrared wave consisting of waves with lengths 768 and 864 nm) and *porphyry UV* (semi-ultraviolet wave composed of waves with lengths 384 and 288 nm).



The author proposes the model of the double propeller shape for bi-chromatic bright wave. In the example form of the double propeller of the bi-chromatic cinnabar red wave, consisting of two monochromatic waves: *magenta IR* 768 nm and yellow 576 nm.

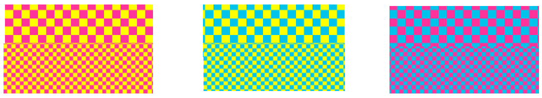
3.4. Additive synthesis generates the chromatic content of heterogeneous bi-chromatic waves and their aggregations

The bi-chromatic heterogeneous waves do not distinguish the primary constitutive elements - that is, the magenta, the yellow and the cyan - because the perception of the colors of light is based on the mechanisms of additive synthesis, which constitutes (according to the writer) the only reason of chromogenesis. In fact, through the additive synthesis of only four bright waves all the shades of colors are obtained as the following tables describe.

a/ The synthesis of 2 single monochromatic waves creates cinnabar red, green and indigo.

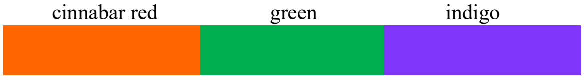
768/576 nm	576/432 nm	432/384 nm
***magenta IR*/yellow**	**yellow/cyan**	**cyan/magenta UV**
= cinnabar red	**= green**	**= indigo**

Monochromatic content of the bi-chromatic waves



Additive synthesis of monochromatic components
= perception of compound colors:

cinnabar red green indigo

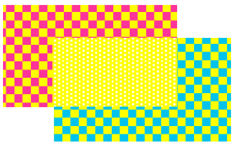


b/ The synthesis of 3 different monochromatic bright waves creates white.

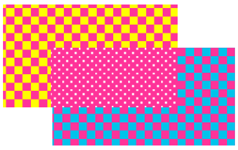
Three monochromatic heterogeneous content				Perception of compound color
			=	white

c/ The synthesis of 2 different bi-chromatic bright waves creates following colors: magenta + white, yellow + white, cyan + white, red and violet.

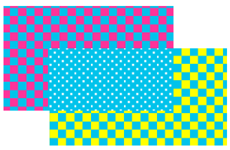
In the overlapping of a cinnabar red wave with a green bi-chromatic wave, the yellow majority monochromatic component is perceived mixed with white.



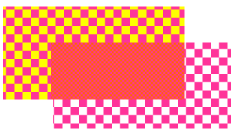
In the overlapping of cinnabar red bi-chromatic wave with a bi-chromatic wave indigo, the majority monochromatic component magenta mixed with white is perceived.



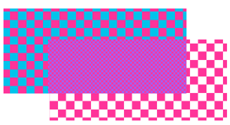
In the overlapping of indigo bi-chromatic wave with a bi-chromatic wave green, the majority monochromatic component cyan mixed with white is perceived.



In the overlapping of a cinnabar red wave with a *porphyry IR* bi-chromatic wave, the color commonly called as red is perceived.



In the overlapping of a indigo wave with a *porphyry UV* bi-chromatic wave, the color commonly called as violet is perceived.



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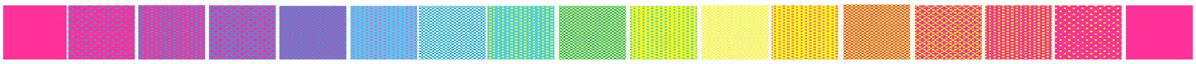
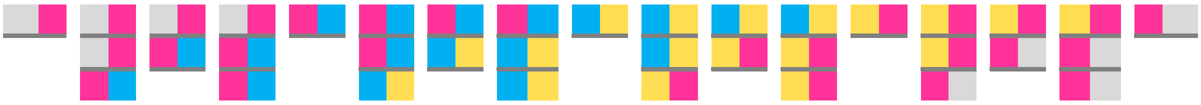
The following table illustrates the aggregations of the bi-chromatic waves: *porphyry IR* and *UV*, cinnabar red, green, indigo, their monochromatic content and the perception of the main colors of the spectrum through the described mechanism of additive synthesis and the average measure of the lengths of the polychromatic waves.



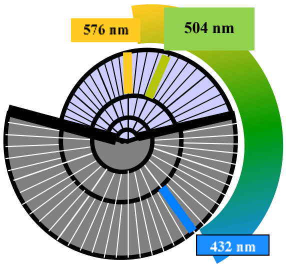
monochromatic components of polychromatic waves

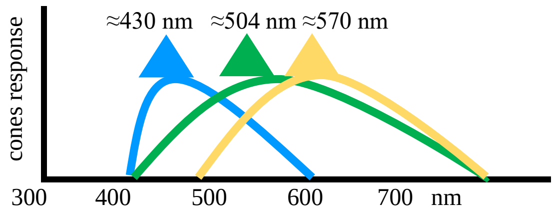


Average measure of the wavelengths of the polychromatic waves consisting of the average of the monochromatic components [nm]																
porphyry UV -1	fuchsia -3	violet -2	plum -3	indigo -1	blue -3	cyan -2	turquoise -3	green -1	lemon -3	yellow -2	orange -3	cinnabar red -1	pumpkin -3	red -2	wine -3	porphyry IR -1
336	360	372	384	408	440	456	472	504	560	588	616	672	720	744	768	816

3.5. The peak of the sensitivity of the cones S, M and L corresponds to the cyan, green (cyan + yellow) and yellow respectively

The measurement of the chromatic sensitivity of the three photoreceptors of the human eyes was carried out from which the maximum sensitivity to the following lengths of the light waves is: about 550-580 nm, 500-540 nm and 420-450 nm. These wavelengths correspond to the colors: yellow, green and cyan. [Val06a]





3.6. ON - OFF process of the phototransduction of light signals

The power of the human brain allows to produce a huge amount of information using the minimum amount of data. In fact, according to the considerations that have been reached during this research, the human photoreceptors (cones and rods) detect only three sensations of color: white, cyan and yellow.

The rods detect the presence of light, translated from the visual areas of the brain in the sensation of white.

In the presence of the information of the rods on the presence of light, the three cones detect only two information: the presence of the monochromatic waves 432 nm and 576 nm, information translated by the brain respectively in sensations of colors: cyan and yellow.

- the cone S absorbs the monochromatic wave of 432 nm (cyan),
- the cone L absorbs the monochromatic wave of 576 nm (yellow),
- The cone M absorbs a green bi-chromatic wave, consisting of a 432 nm cyan monochromatic wave and a 576 nm yellow monochromatic wave.

cones:							
S			M			L	

Note that the cones measurement system is binary. It consists in reading only two cyan or yellow stimuli: individually (cones S and L) and together (cones M).

Thanks to the on-off mechanism of phototransduction of the bright signals and the additive synthesis mechanism, the four types of photoreceptors: rods, cones S, L and M are able to provide eight chromatic sensations:

- the rods with ON signal indicate the presence of light translated into sensation of white color and OFF signal indicate the absence of light translated in a sensation of black color;
- The S cones with ON signal indicate the presence of the monochromatic wave 432 nm = cyan and with OFF signal indicate the absence of cyan light translated into the sensation of the complementary color containing yellow and magenta and synthesized as cinnabar red;
- The L cones with ON signal indicate the presence of the monochromatic wave 576 nm = yellow and with OFF signal indicate the absence of yellow light translated into the sensation of the complementary color containing cyan and magenta, equal to indigo;

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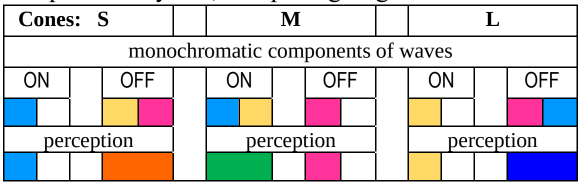
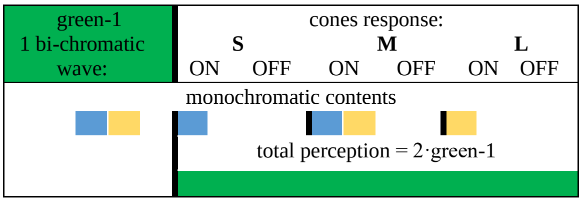
- The M cones with on the ON signal indicate the presence of two monochromatic waves 432 nm = cyan and 576 = yellow which through the mechanism of synthesis additive give the feeling of green; the M cones with OFF signal inform of the absence of cyan + yellow waves, message translated into the feeling of complementary color containing only magenta.

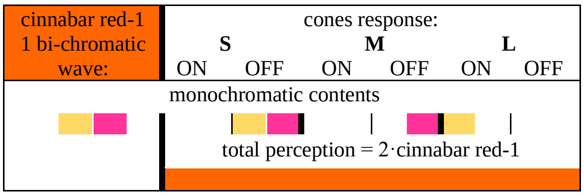
In this way each cone detects one color and its complementary tint, composing together the white.

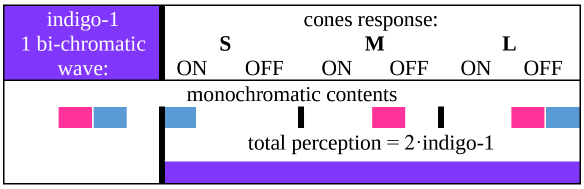


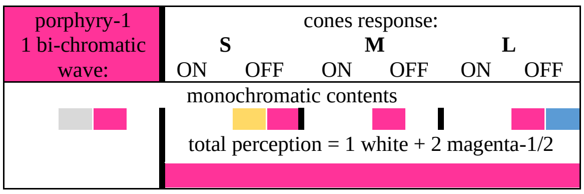
Consequently, the bi-chromatic waves (indigo-1, green-1 and cinnabar red-1) and their binary aggregations (viola-2, cyan-2, yellow-2, red-2, magenta-2) are coded in the following way by the ON-OFF system:

a/ Single bi-chromatic wave.

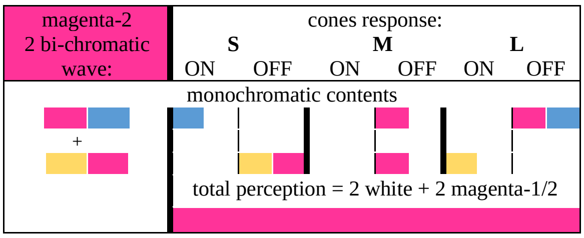


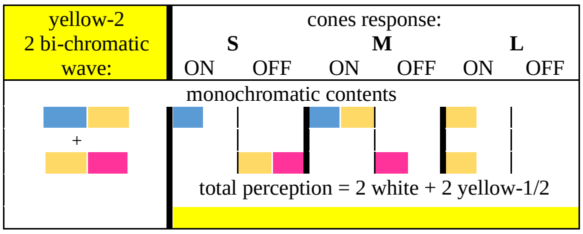


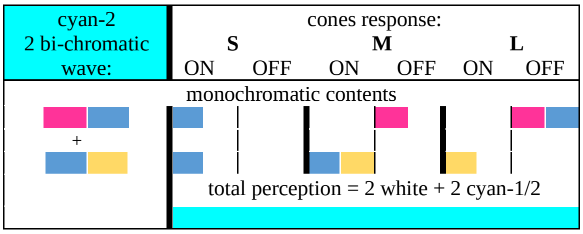


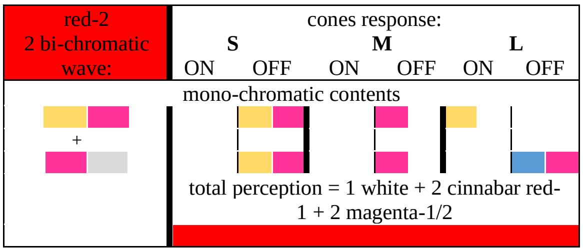


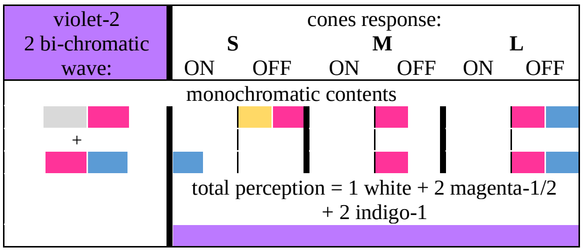
b/ *Binary* bi-chromatic waves.





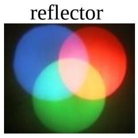




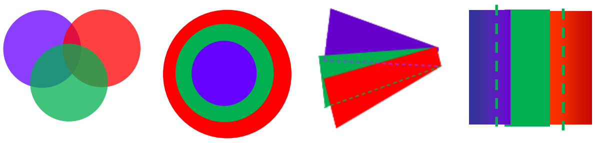


The bi-chromatic composition of the bright waves and the on-off system of the phototransduction of the chromatic signals outlined in this book is confirmed by the classic example of additive synthesis. In fact, the overlap of red and green lights produces yellow + white, the overlap of red and indigo lights produces magenta + white, the overlap of indigo and green lights produces cyan + white and the overlap of indigo, red and green lights produces white. The traditional approach does not explain the reasons why these color changes occur.

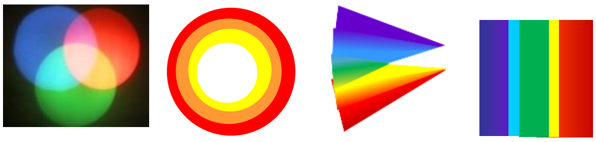
The colors of the stars and decomposition of light in the prism or in the rainbow takes place with the same mechanism of the additive synthesis generated by the overlap of the bi-chromatic waves cinnabar red/green, green/indigo and cinnabar red/indigo.

The rims overlap laterally in the bundles of a reflector	The rims overlap starting from the center in a star	Cones overlap in the prism	Arches overlap in the rainbow
			

Scheme of the overlapping of the 3 bi-chromatic waves



Chromatic effect scheme



3.7. Deficit of color vision due to the dysfunction of the process of phototransduction of light signals

Each color we see produces generic effect on the rods (presence of light) and specific on-off responses from the three cones. The following table illustrates how the colors of the natural spectrum are coded in system shown below. (The natural spectrum differs from the spectrum produced by the RGB system from the different way of generating the purple colors which in the first case are produced by the overlapping of the indigo-1 and *porphyry UV*-1 waves and in the second case by the overlapping of the indigo-1 and red-2 waves.)

Codification ON-OFF of cones S, M, L

signal **ON** [nm]

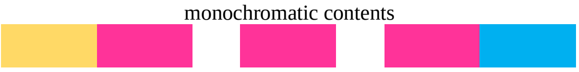
cones: S	M	L
432 cyan	504 green	576 yellow

monochromatic contents

signal **OFF** [nm]

cones: S	M	L
672 cinnabar red	384, 768 magenta	408 indigo

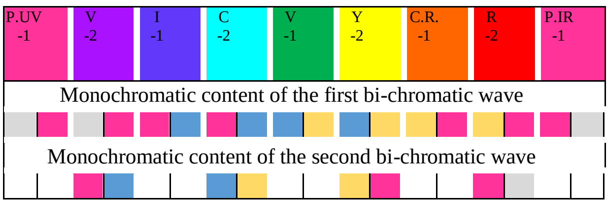
monochromatic contents



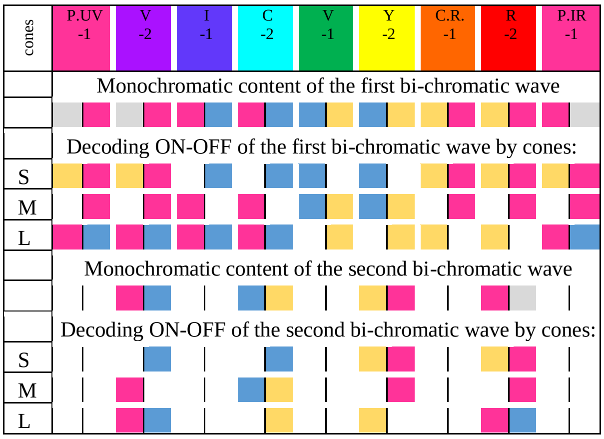
Normal view of natural spectrum

The following tables present:

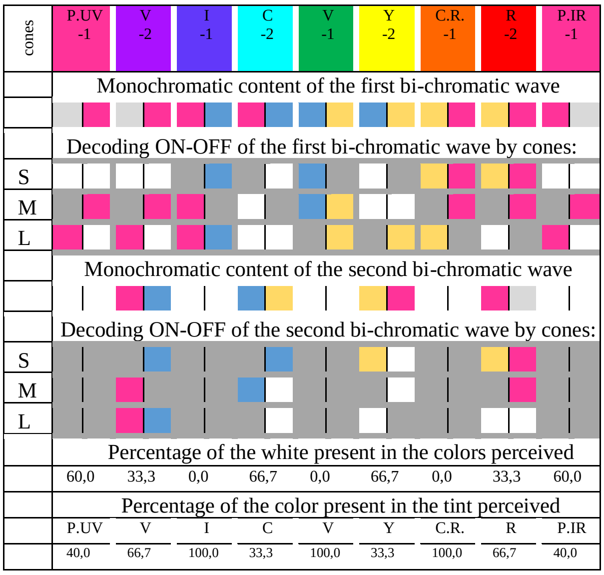
a/ The monochromatic content of the bi-chromatic waves: single and binary of the natural spectrum and their perception;



b/ Contribution of the three cones in the formation of the chromatic map through the ON-OFF system;



c/ Actually chromatic map generated by the additive synthesis of white.



The tables below illustrate the deformation of the vision of the spectrum in the case of the absence of the signals from the cones M and S, where therefore the phototransduction of the ON-OFF signals only works by the cones L. This dysfunction will be *called L-monopsia* here. (In literature this dysfunction is called Protanopia).

L- monopsia

signal **ON** [nm]

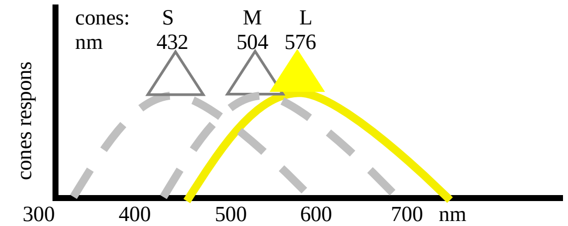
S	M	L
432 cyan$_{1/2}$	**540 green-1**	**576 yellow$_{1/2}$**

monochromatic contents

signal **OFF** [nm]

S	M	L
672 nm cinnabar red-1	**384, 768 magenta$_{1/2}$**	**408 nm indygo-1**

monochromatic contents



The following tables present:

a/ The monochromatic content of the bi-chromatic waves: single and binary of the natural spectrum and their perception and the contribution of cones L only in the formation of the chromatic map through the ON-OFF system for the decoding of the monochromatic content of the composed colors displayed up (*L-monopsia*);

cones	P.UV -1	V -2	I -1	C -2	V -1	Y -2	C.R. -1	R -2	P.IR -1
	Monochromatic content of the first bi-chromatic wave								
	Decoding ON-OFF of the first bi-chromatic wave by cones:								
L									
	Monochromatic content of the second bi-chromatic wave								
	Decoding ON-OFF of the second bi-chromatic wave by cones:								
L									

c/ Actually chromatic map generated by the additive synthesis of white in the case of *L-monopsia*;

cones	P.UV -1	V -2	I -1	C -2	V -1	Y -2	C.R. -1	R -2	P.IR -1
	Monochromatic content of the first bi-chromatic wave								
	Decoding ON-OFF of the first bi-chromatic wave by cones:								
L									
	Monochromatic content of the second bi-chromatic wave								
	Decoding ON-OFF of the second bi-chromatic wave by cones:								
L									
	Percentage of the white present in the colors perceived								
	0,0	0.0	0,0	100.0	0,0	0,0	0,0	100,0	0,0
	Percentage of the color present in the tint perceived								
	I	I	I	C	Y	Y	Y	R	I
	100,0	100,0	100,0	0,0	100,0	100,0	100,0	0,0	100,0

The vision with the contribution of the only L cones with (*L-monopsia*) therefore deforms as follows the perception of the colors of the natural spectrum:

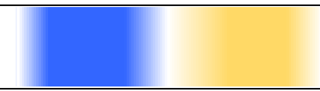
Normal vision

View of the natural spectrum without contribution of the cones S ad M (*L-monopsia*); The contribution of the only L cones.

- Cyan is perceived white,
- Green, yellow and orange are perceived yellow,
- Red is perceived white.

This dysfunction, which according to the writer must be attributed to the functioning of only cones L is identified in literature as the dysfunction just of the cones L, responsible for the vision of red (protanopia).

The table below is compared to the graph of the deformation of the vision of the colors of the spectrum in RGB by people with protanopia (presumed dysfunction of the cones L) obtained experimentally, with the graph of the deformation of the vision of the colors of the spectrum in RGB by the *L -monopes* (dysfunction of the cones S and M) obtained with the analytical method of this work.

a/ Vision of the spectrum in RGB by people with protanopia. [AVI22a]	
b/ Vision of the spectrum in RGB by people with *L-monopia.*	

Note a substantial similarity between the two draws. In the same way with this method the spectrum is obtained in the case of the dysfunction of the cones L, where the measurement of light and phototransduction is made only by the cones S and M (*L-anopsia*).

cones	P.UV -1	V -2	I -1	C -2	V -1	Y -2	C.R. -1	R -2	P.IR -1
	Monochromatic content of the first bi-chromatic wave								
	Decoding On-Off of the first bi-chromatic wave by cones:								
S									
M									
	Monochromatic content of the second bi-chromatic wave								
	Decoding On-Off of the second bi-chromatic wave by cones:								
S									
M									

Actually chromatic map generated by the additive synthesis of white in the case of *L-anopsia*;

cones	P.UV -1	V -2	I -1	C -2	V -1	Y -2	C.R. -1	R -2	P.IR -1
	Monochromatic content of the first bi-chromatic wave								
	Decoding On-Off of the first bi-chromatic wave by cones:								
S									
M									
	Monochromatic content of the second bi-chromatic wave								
	Decoding On-Off of the second bi-chromatic wave by cones:								
S									
M									
	Percentage of the white present in the colors perceived								
	0,0	60.0	0,0	60.0	0,0	100,0	0,0	0,0	0,0
	Percentage of the color present in the tint perceived								
	C.R.	P.UV	I	C	T	Y	R.	R.	R.
	100,0	40,0	100,0	40,0	100,0	0,0	100,0	0,0	100,0

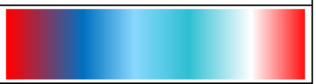
Normal vision

Vision with the contribution of the S and M cones (*L-anopsia*)

Yellow is perceived white, green is perceived turquoise (green/cyan), violet is perceived pink, the orange colors are not distinguished from the reds, the orange/yellow colors are perceived pink.

According to the conclusions of this research, this dysfunction is erroneously identified in literature such as the dysfunction of the S cones, responsible for the vision of blue (Tritanopia).

The table below is compared to the graph of the deformation of the vision of the colors of the spectrum in RGB by the Tritanopes (alleged dysfunction of the cones S) with the graph of the deformation of the vision of the colors of the spectrum in RGB by the *L -anopes* (dysfunction of the cones L) obtained with the analytical method of this work.

a/ Vision of the spectrum in RGB by people with tritanopia [Wik22a]	
b/ Vision of the spectrum in RGB by people with *L-anopes*.	

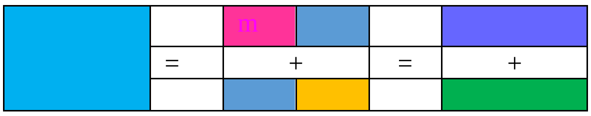
The similarity between the two graphic is evident. Note the absence of yellow and the presence of incongruent blue to the traditional interpretation of this dysfunction.

CONCLUSION

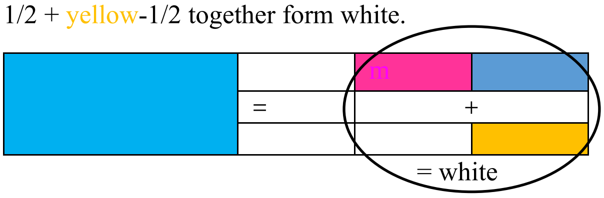
All these reasoning was necessary to answer our initial questions. Here are the answers formulated according to this research:

Question 1. The cyan is seen white by the Protanopes (*L-Monopes* second definition of this research) because:

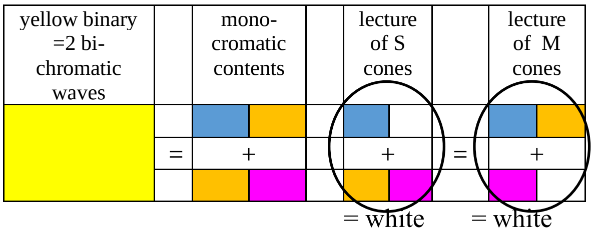
- The cyan of the spectrum is made up of indigo and green, composed respectively by *magenta UV*/cyan and cyan/yellow monochromatic waves;



- When work only L cones the cyan-2 is perceived as an indigo-1 + yellow-1/2, then magenta-1/2 + cyan-1/2 + yellow-1/2 together form white.



Question 3. In the same way, the yellow composed of the spectrum (yellow-2) is perceived white in the case of the function only of the cones S and M.



Question 2 and 4. For Protanopes (*L-Monopes*) green and yellow are seen as yellow because they are able to perceive only the yellow monochromatic component from bi-chromatic waves that make up these colors. In the same way for the Tritanopes (*L-Opsia*) cyan and green are seen cyan. They only perceive the cyan monochromatic component from the bi-chromatic waves that make up these colors.

Analysis of dysfunctions in the vision of colors can allow us to hypothesize the polychromatism of all light waves, not only of white.

A more precise knowledge of the composition and parameters of the bright waves could give a new impulse in the search for simplification and improvement of the performance of the production of colors in computers.

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