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LIGHT AND COLOURS IN HUMAN ACTIVITIES

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The results in scholar activities at physics hours in three high schools from Vaslui and Iasi districts show that the colour nuances influence the nervous system and the individual mental state. In the experiments organized using light green screens and black pencils or yellow screens and green pencils the grades were higher.
Keywords: colour, nuance, mechanism of coloured sight.

O serie de rezultate în activităţile şcolare la orele de Fizică în trei licee din judeţele Vaslui şi Iaşi au arătat ca nuanţele influenţează sistemul nervos, şi starea mentală individuală. În experimentele organizate cu table gri şi carioka negre sau table galbene şi carioka verde notele obţinute de elevi au fost mai mari.
Cuvinte-cheie: culoare, nuanţă, mecanismul vederii în culori.

INTRODUCTION

Optical radiations from the visible range (400-800nm) are known as light.

Objects are perceived through the alternation of light and shadow created by the light sources.

Light is emitted by primary sources (sun, lamps) or can be reemitted by secondary sources illuminated by the former. Reemission is based on reflection, diffusion, refraction and so on.

Newton decomposed light using a quartz prism in its primary coloured components which give the sensation of red, orange, yellow, green, blue, indigo, or violet. The experiment made by Newton demonstrated for the first time that light is a superposition of coloured radiations obtained in the visible spectrum. The images, tables or graphs representing the light intensity dependence on wavelength is called spectrum.

The characteristic of the bodies through which a person observes differences between two adjacent surfaces with the same shape, equal dimensions and identical structures is called colour. The colour is a psychophysical and sensorial – receptive reality. From the physical point of view, the colours represent a restricted spectral range of light characterized by restricted values of wavelength and bandwidth, named colour stimuli.

The colour stimuli create the visual sensations by impressing the cones from the retina. The colour is only for the visual reception.

From the psychophysical point of view the intensity of colour sensation is proportional with the flux density transported by physical stimulus. From a sensorial perceptive point of view, the colour is a sensation characterized by a series of basic properties: nuance, luminosity, saturation.

Nuance is expressed by the words red, yellow, green, greenish-yellow, blue-green, grey, and it is connected to the spectral composition of the stimuli. The grey nuances are called neutral colours.

Luminosity is the colour quality expressed by brightness and it is an energetic characteristic of colour.

Saturation is the attribute of colour that helps distinguishing between two colours having the same nuance and brightness. It expresses the colour purity, giving us information about the presence of neutral colours in a colour stimulus of a certain nuance.

Colour is a three dimensional notion because it is characterized by three attributes:

$$S(S) = X(X) + Y(Y) + Z(Z) \qquad (1)$$

Relation (1) shows that S quantity of colour stimulus S can be expressed by three various stimuli $(X),(Y),(Z)$ when they are mixed in quantities X, Y, or Z.

The colour stimulus achieved by mixture of three colour stimuli is considered to be obtained by additive composition. When a colour stimulus is obtained by eliminating a colour stimulus (absorbed or diffused), the process is called subtractive composition.

According to the results obtained in studies on colour, some laws were established:

- The human eye can establish three attributes of colour: nuance, luminosity, saturation.
- The colour can be continuously changed by a continuous variation of a flux of component stimuli.
- A mixture of two colour stimuli of the same colour induces a sensation of the same colour as the component visual stimuli, independent, on the spectral composition of the two stimuli.

The rules of colour stimuli composition are equivalent to the rules of mathematical operations (addition and subtraction) of colour; algebra has been developed on the colour space.

Comparing formula (1) which expresses the space position of vectors by three basic vectors (three versors of a coordinate system), the colour space in which each colour is represented by a point can be elaborated. In this analogy, the symbols (X), (Y), (Z) of the colour stimuli are equivalent to the versors and X, Y, Z are named colour components. In order to elaborate the colour space, the basic stimuli were chosen.

The spectral stimuli (with wavelengths form very short spectral range named bandwidth) are obtained by white light decomposition. The nuances of the spectral stimuli range are listed Table 1.

Table 1. Nuances and corresponding wavelengths of light

Nuance	**Λ(nm)**	**Nuance**	**Λ(nm)**
Red	630	Green	560- 490
Orange	630- 590	Blue	490- 450
Yellow	590- 560	Violet	450

The mixture of all spectral stimuli gives the stimuli of white light (neutral colour). Two colour stimuli which mixed in a determined proportion produce the neutral colour are called complementary colour stimuli. When a colour stimulus is extracted from neutral stimuli, the result is the complementary colour stimulus of the extracted one.

Three basic colour stimuli were chosen from the spectral stimuli (R), (G), (B) - RED, GREEN, BLUE with Λ=700nm, Λ=546.1nm respectively Λ=435.8nm corresponding to the basically colour stimuli. The average spectral components $\bar{R}(\Lambda)$,$\bar{G}(\Lambda)$,$\bar{B}(\Lambda)$ of all stimuli were measured.

Basic fictive stimuli were introduced with positive components because $\bar{R}(\Lambda)$, $\bar{G}(\Lambda)$,$\bar{B}(\Lambda)$ are not all positive. The basic fictive stimuli were noted by $(X),(Y)$ and (Z) with their components X, Y, respectively Z.

They were adopted in 1931 by the International Comission on Illumination and define the Colorimeter Standard Observer.

The standardized values for the spectral stimuli having wavelengths in the spectral range (280-770nm) were listed. The basic stimulus in the Standard Colorimeter Observer is the efficiency of the eye cones:

$$\bar{V} = V(\Lambda) \qquad (2),$$

$V(\Lambda)$ - lighting efficiency of the eye cones. The equienergetic neutral (grey) colour stimulus has the components:

$$\overline{X_\omega} = \overline{Y_\omega} = \overline{Z_\omega}=0,3333 \qquad (3)$$

Colorimeters (trichromatic photometers) were realized in order to measure the colours.

A scheme of trichromatic photometer is illustrated in Fig. 1.

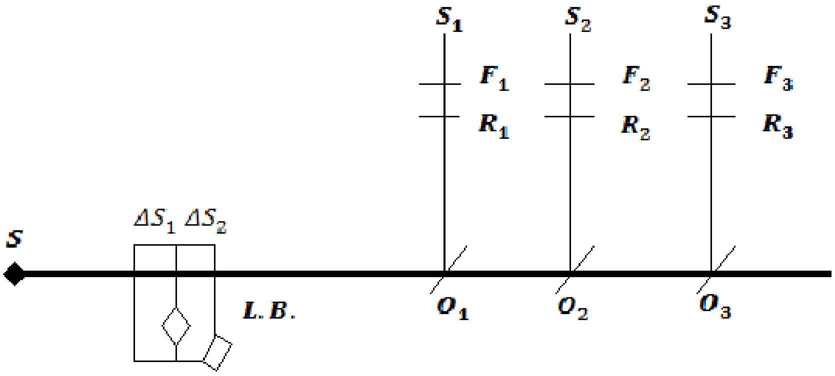

Fig. 1. The trichromatic photometer scheme

$\Delta S_1, \Delta S_2$ - diffusing surfaces for which the observed colour stimuli are the same with those used for their illumination.

ΔS_1 -is illuminated by the source S and ΔS_2 is illuminated by three radiations emitted by the sources S_1, S_2 *and* S_3 (which produce different colour sensations for an adequate choice of filters F_1, F_2 *and* F_3 and reducible diaphragm R_1, R_2 *and* R_3 for the light fluxes.

THE MECHANISM OF COLOURED SIGHT

The central fovea of the human eye (in the yellow spot area) contains cones and sticks, cells specialized in intercepting and analysing visible radiations. The central retina contains fovea with cones specialized in absorbance in the red, green and blue spectral ranges. The cones from the central fovea are specialized in the chromatic diurnal sight; they discriminate chromatic shades and nuances. The cones contain special pigments sensitive to a specific colour stimulus. Three pigments were evidenced in the human cones: the “red” cones have a pigment that absorbs in the red and orange spectral ranges, the “green” cones preferentially absorb the green range and the “blue” cones absorb radiations from the blue of visible range. The map of the visual range of each eye may be built using a special device called perimeter. All colours were observed in the central fovea; the red and green colours have a more restricted area, compared to yellow and blue. Besides the chromatic area, the human retina contains sticks, which are sensitive to neutral nuances. The sticks are able to discriminate between achromatic nuances from white to black. They are responsible for the night sight, or for twilight observations. Each colour from the colour space can be obtained by the superposition of three colour stimuli (red, green, blue) with different luminosity and saturation. The interactions between three types of the human photo receivers determine the whole range of chromatic shades and colours. Thus, if the incident light on the human eye is monochromatic, the cones give the sensation of the nuance corresponding to the absorbed spectral range. Red, green, or blue are called primary colours. When the three types of the diurnal receivers are simultaneously excited by light equienergetic components (red, green, blue) the sensation of white is obtained. Every nuance in the colour space has a corresponding complementary nuance. The complementary nuances give neutral white colour when they are mixed. The incident radiative flux ($\Delta\Phi_i$) of a primary radiation illuminating the body surface can be transmitted ($\Delta\Phi_t$), absorbed ($\Delta\Phi_a$), reemitted in a fixed direction by reflection ($\Delta\Phi_r$) or in all directions by diffusion ($\Delta\Phi_d$). The bodies are observed by the visible radiations returning from their surfaces by reflection or diffusion phenomena. The conservation law of energy in the vicinity of the observed surface can be written as:

$$\Delta\Phi_i = \Delta\Phi_t + \Delta\Phi_a + \Delta\Phi_r + \Delta\Phi_d \quad (4)$$

or

$$1 = \frac{\Delta\Phi_t}{\Delta\Phi_i} + \frac{\Delta\Phi_a}{\Delta\Phi_i} + \frac{\Delta\Phi_r}{\Delta\Phi_i} + \frac{\Delta\Phi_d}{\Delta\Phi_i} \quad (4')$$

$$1 = T + A + R + D \quad (5)$$

The ratios:

$$T = \frac{\Delta\Phi_t}{\Delta\Phi_i},\ A = \frac{\Delta\Phi_a}{\Delta\Phi_i},\ R = \frac{\Delta\Phi_r}{\Delta\Phi_i} \text{ and } D = \frac{\Delta\Phi_d}{\Delta\Phi_i} \quad (6)$$

are called factors of transmission, absorbance, reflectance, and diffusion.

Based on the values of these factors, the surfaces are classified as it follows:

- Absolute transparent T=1
- Absolute absorbent (black) A=1
- Absolute reflectant R=1
- Absolute diffusive D=1

The bodies are observed through the radiations reemitted by their surfaces. Only the reemitted radiations that are complementary to those absorbed come back to the human eyes. So, only the colours complementary to those absorbed by the body surface will give the body colour.

Let us suppose that a surface absorbs in green. In white light, the surface is observed as being red. The same surface can give the filling to be black if from the incident beam the red color is missing.

The body colours are considered psychophysical phenomena because in appreciating them, both the visual and mental mechanisms are important.

Every person perceives the colours differently, because of the influence they exert on the human psychic, inducing different feelings. Some colours can irritate, or make us nervous, or they can give us the feeling of coldness, or loneliness, whereas some others can induce states of reverie, satisfaction, or they cheer us up.

COLOUR IN SOCIAL LIFE

Due to their psychological effects, colours can be utilized in social activities, in the treatment of some diseases, or for didactic purposes, in order to induce the mood for acquiring new knowledge. The colours stimulate and change the spatial proportions "enlarging" or "reducing" the dimension of the objects; they can "warm up" or "cool up'' the closed spaces. Some psychological effects of colours are listed in Table 2.

Table 2. The colour effects

NR.	COLOUR	CHARACTERISTICS
1.	White	Inspires expansion, easiness, suavity, purity, coldness, robustness
2.	Black	Induces quietness, depression, shyness and tender emotions
3.	Grey	Attenuates the action of the other colours
4.	Red	Excites, stimulates, mobilizes, facilitates the ideas association; it is a very warm colour
5.	Orange	Induces optimism, emotions, feelings of closeness and health, states of joy.
6.	Yellow	Induces states of vigilance predisposes to communication, stimulates. It is a warm colour.
7.	Green	Induces states of relaxation, meditation, equilibrium, contemplation.
8.	Blue	Induces calmness, quietness, reverie. It can slow down intellectual activities.
9.	Purple	Induces quietness, sadness, melancholy; it can discourage, being a very cold colour.

The colours influence one another. Therefore, near blue, all colours are cold, while near red, the same colour becomes warmer. Primary colours are vivid, inspiring dynamism, joy, movement. A primary colour combined with other colours gets pale, being deprived of luminosity and purity.

Colour luminosity is also important in inducing feelings. A colour seems deeper with the decrease in its brightness. The chromatic contrasts can influence our feelings. The happiest chromatic contrasts are blue - white, black - yellow, green - red.

The black - white contrast is not a good choice, leading to the highest level of fatigue of the human eyes. The blackboards on which white pens are used are very tiresome, and they are not indicated for student activities, given the fact that they increase fatigue and attenuate concentration. The best choice for boards would be a light yellow surface on which black fibre pens are used or a white surface and green fibre pens.

In the instructive-educational processes, the colours can positively influence perception, attention, increasing the degrees of understanding and memorizing.

Some colours or colour contrasts determine the degree of focusing by a better nervous connection. They can develop imagination, creativity, memory. Children raised in a chromatic varied environment with well - chosen nuances have a higher intelligence and imagination level compared to those raised in an achromatic environment. Colour nuances influence the nervous system and the individual mental state. For example, white determines the best concentration, blue and black slow down the intellectual activity, stimulating inhibitions. Red stimulates intellectual activity favouring the associations of ideas; yellow increases the ability to focus, and green stimulates creativity and the free association of ideas.

COLOURS IN INCREASING THE EFFICIENCY OF THE INSTRUCTIVE EDUCATIVE ACTIVITIES

In our experiments, three sets of tests containing questions and problems of average difficulty were typed on:

- Blue paper with black pencil (experiment I)
- Light-green paper with black pencil (experiment II)
- Yellow paper with green pencil (experiment III)

Three classes comprising 23, 23 and 22 students from high schools in the Vaslui and Iasi Districts participated in the experiments, each class receiving all three coloured tests. The experiments were carried out in the same day during three hours separated by one sports or musical education class, in order to assure a relaxing pause between the tests for each class.

The results are illustrated in table 3 and Fig. 2.

Table 3. Number and percent of students obtaining grades from 1-10 in written examinations using different paper and pencil colours

GRADE	EXPERIMENT I (No. of students)	P%	EXPERIMENT II (No. of students)	P%	EXPERIMENT III (No. of students)	P%
2	2	2.9	0	0	0	0
3	4	5.9	3	4.4	2	2.9
4	6	8.8	4	5.9	3	4.4
5	9	13.2	10	14.7	11	16.2
6	12	17.6	13	19.1	18	26.5
7	15	22.1	19	27.9	13	19.1
8	12	17.6	12	17.6	9	13.2
9	5	7.4	6	8.8	7	10.3
10	3	4.4	1	1.5	5	7.4
Obs.	Blue + black pencil		Light green + black pencil		Yellow + green pencil	

From Table 4 it results that the number of grades equal or higher than 7 is the smallest in the third experiment, although in this experiment, the number of grades of 9 and 10 is considerably high.

The results obtained by using various nuances of paper and pencil in this experiment are not very different, but the use of light green and yellow contributed to the increase in the number of grades of 9 and 10, proving that these nuances can determine an increase in the level of focus and stimulate creativity and the free association of ideas.

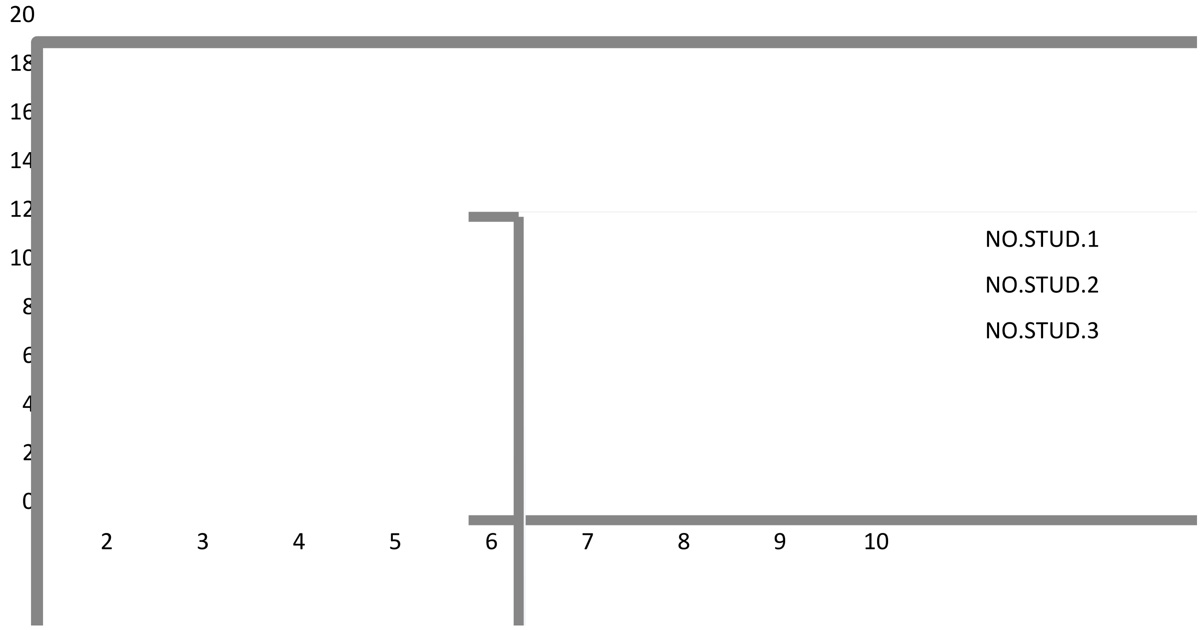

Fig. 2. Number of students vs. Obtained grades in experiments I, II, III

Table 4. Number and percents of grades depending on nuances of paper and pencil

VALUE OF GRADES	EXPERIMENT I	P%	EXPERIMENT II	P%	EXPERIMENT III	P%
≥ 7	35	51.5	38	55.9	34	50.0
≥ 8	20	29.4	19	27.9	21	30.9
9.10	8	11.8	7	10.3	12	17.6
Obs.	Blue– black pencil		Light green- black pencil		Yellow-green pencil	

CONCLUSIONS

The colour of didactical materials can improve the results obtained in school activities. Every person perceives the colour differently to the influence the colour exerts on the human psychic inducing different feeling.

In the instructive – educational processes, the colour can positively influence perception, attention increasing the degrees of understanding and memorising.

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