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YELLOW AS A DOMINANT TONE

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Original scientific paper

In the era of multimedia communication, it is important to investigate how the color of the environment influences the psycho-physical experience of color, which can often have impact on the working atmosphere of the working environment. It would be wise to consider the psychology of color when designing marketing materials. Be it a business card, a brochure, a web site, posters or other material, color choices are being made. Colors not only enhance the appearance of the item – they also influence our behavior. The impact that the colors we use will have on our target audience should be considered. This paper emphasizes the experience of yellow in cases when the environment is predominated by achromatic tones and complement pairs of color tones. Due to the complexity of colors as an interdisciplinary field in science, in this paper it was intended to connect the computer objective evaluation with the psychological perception of color, and to contribute to the exact promotion of the mathematical-statistical methods for communicating with the color in the environment in which it is located. Investigations were carried out with a yellow tone, which, because of its specificity, its own high-lightness, is the dominant color. The research complies with the psychophysical method: the method of constant stimulus – the value of lightness, defining the influence of the background color on the experience of the yellow color. The statistical data analysis has been conducted by means of descriptive statistics; the Kruskal-Wallis ANOVA and Median tests have been used. It is confirmed that the difference between the experienced position of the sample and the actual position, depends on the color of the background.

Keywords: *objective evaluation of color, psychophysical method, Kruskal-Wallis ANOVA, yellow, the background color*

Žuta boja kao dominantni ton

Izvorni znanstveni članak

U vremenu multimedijske komunikacije važno je istražiti kako boja okoline utječe na psihofizički doživljaj koji često ima utjecaj na radnu atmosferu u radnom okruženju. Psihologija boje odlučujuća je i kod dizajniranja marketinškog materijala. Izbor boje je prisutan kod izrade poslovnih posjetnica, internet stranica, postera ili drugo. Boje ne utječu samo na izgled proizvoda-također utječu na naš doživljaj. Dobrim izborom boje postiže se cilj. Dat je naglasak na doživljaj žute boje u slučajevima kada je okolina dominantnih akromatskih i komplementarnih tonova. Obzirom na kompleksnost boje, kao interdisciplinarnog polja znanosti, u ovom radu bila je namjena povezati računalno objektivno vrednovanje sa psihološkim doživljajem boje i pridonijeti promociji matematičko-statističke metode kojom se može predvidjeti ponašanje boje u okolini. Istraživanja su provedena sa žutim tonom koji je zbog svoje specifičnosti, vlastite velike svjetline, dominantna boja. Ispitivanja su usuglašena sa psihofizikalnom metodom, metodom konstantnog stimulusa-utjecaj svjetline, definiranje utjecaja boje pozadine na doživljaj žute boje. Statistička obrada je provedena primjenom Kruskal-Wallis ANOVA i Medijan testa. Potvrđeno je da razlika između doživljene pozicije uzorka i stvarne pozicije ovisi o boji pozadine.

Ključne riječi*: objektivno vrednovanje boje, psihofizikalne metode, Kruskal-Wallis ANOVA, žuta boja, boja pozadine*

1 Introduction

The history of colour science has its origins in the era of Greek philosophers Plato and Aristotle. Newton, Helmholtz, Hering, Munsell, Land and Ostwald continued with the scientific approach as it was them who provided the basis for understanding and comprehension of the colour phenomena [1, 2, 3]. They proved that the perception of a colour will depend and change depending on the parameter changes and the observing conditions, such as the observer, light source, background colour, energy level of illumination and so on [3, 4, 5, 6]. Common methods are used for the psychophysical experience of colour: the boundary method, the method of constant stimulus and the Steven's evaluation method. The most commonly used method is the method of constant stimulus. This method estimates the psychophysical experience of colour for every psychological colour attribute (H, L and C) conditioned by the background colour (environment), different light sources and so on [5, 6, 7, 8].

The paper examines the influence of the background colours – the achromatic basis (white, grey, and black) and complementary pair blue-yellow on the psychological experience of the yellow tone [8, 9, 10, 11]. The tests were based on a comparison of objective spectrophotometric method with a psycho-physic experience of color. The statistical data analysis was conducted using the Kruskal-Wallis ANOVA and Median tests [12, 13].

2 Methodology

The research on the yellow tone was done for the purpose of defining the relation between the color and the background (environment colour). The yellow (H^*= 090) is sequenced according to chroma (C^*) and lightness (L^*) on the basis of the following background characteristics: achromatic (white; L^*=96, grey; L^*=50 and black; L^*=10), yellow (H^*=90, L^*=90, C^*=60*) and blue (H^*=270, L^*=40, C^*=40*).

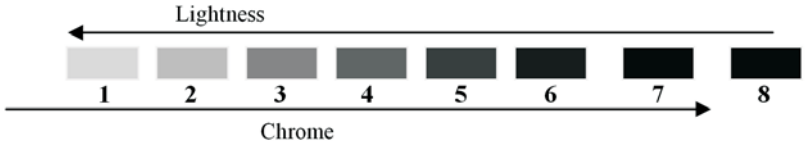

Figure 1 Layout of the set sample positions on the background from 1 to 8

2.1.1
Objective analysis

Coloristic characteristics for each position of yellow color are defined with a remission spectrophotometer Datacolor 600 CT, D_{65}, *d*/8°, and they are shown with a relation between *C**/*Y* and *C**/*L**, Figs. 2 and 3.

Based on the coloristic values *C** and *L**, samples are arranged on each background according to a flow chart, Fig. 1. The position of every color is marked by positions from 1 to 8.

2.1.2
The visual assessment

The visual assessment of the colored samples was conducted on 30 observers (21 to 40 years of age). Visual evolution was carried out according to the standard of light source D_{65}, the distance between the observer and the sample being 60 cm and the angle being 10°.

The observers were asked the following questions:

Does the position of the equal yellow tone on the backgrounds: white, grey, black, blue and yellow provide the same psychological experience for the value of lightness (L) and chrome (C) according to the positions arranged on the pattern?

The placement of every position of every observer depending on the background is analyzed statistically and the experienced position of the yellow color is shown, with the values of standard deviation, Tab. 1.

The statistical analysis of the visual assessment is conducted by an application program (StatSoft). The corresponding non-parameter statistical tests, the Kruskal-Wallis ANOVA and the Median test, were used. The results are the values shown graphically in Figs. 4 and 5.

3
Results and discussion

With the spectroscopic-instrumental method color is determined objectively, and it is not dependent on the environment and the observer, while the psychological experience of color is a real state of communication of the environment and color. For each position of the yellow tone on the background, their coloristic values were obtained, and they were shown with the relation *C**/*Y* and *C**/*L**, Figs. 2 and 3.

For the value of *Y* often is implied, on the bases of colorimetric definitions, that it represents a direct evaluation of lightness. It can be assumed, Fig. 2, that for each tone of color the sensitivity to the psychological

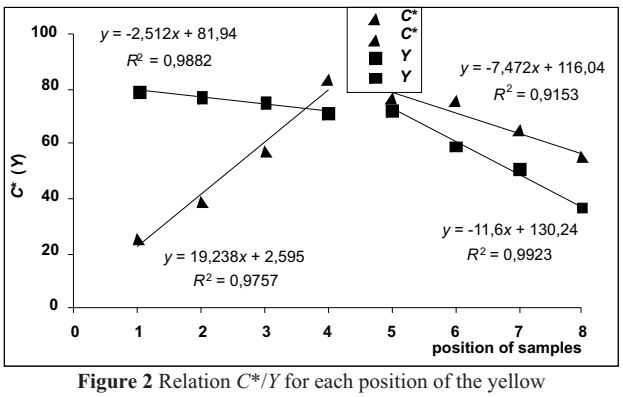

Figure 2 Relation *C**/*Y* for each position of the yellow

experience of the observer will be reduced with smaller differences between the *Y* and *C**.

For example, it can be expected that the observer's sensitivity to the psychological experience of a yellow tone will be smaller if the differences between the *Y* and *C** are smaller by 10 units. Therefore, the "threshold" of low sensitivity is attributed to a yellow tone on the positions of samples higher than position 4. However, these values are not fully correlated with the psychological perception of color. Namely, each color that is saturated with its own tone has a lower lightness - *L**. It can be assumed, depending on the color tone, that in a moment of equalization of the value *L** with *C**, resolution of samples between themselves will be more difficult, i.e., the psychological experience of the color in the entire area will depend on the subjective assessment of the observer and the background color. For the yellow color tone, Fig. 3, the "threshold" of sensitivity on the positions higher than 4 sample positions corresponds to the values obtained for the *Y* and *C**, and is correlated with the spectral characteristics of yellow tone, respectively lightness and color, what exactly makes this color dominant.

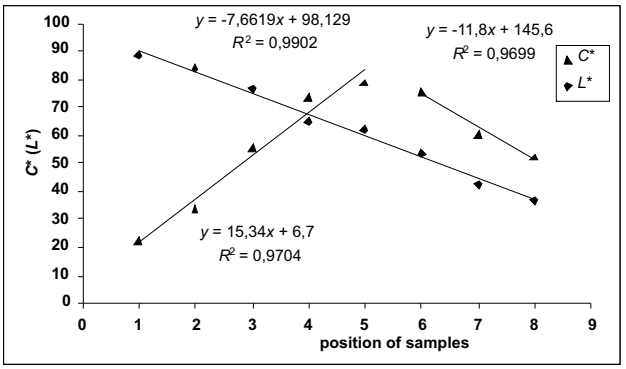

Figure 3 Relation *C**/*L** for each position of the yellow

Based on these considerations, an objective spectrophotometric method can contribute to the selection of the relation between the color and the background especially when the colored object is required to maintain its own characteristics.

The psychological experience of color is a real state of communication between the environment and the color, and it will depend on the source of light, energy of light, viewing angle, and especially on the observer and his psychological state (health condition). In this paper, tests were conducted in constant conditions, as described in the Chapter 2. (methodology), and obtained results are solely answers of the observers to the questions.

The method of ranking- setting is considered to be the simplest because the examinee himself interactively controls the value of stimuli, and, with the most direct method of evaluation of the "threshold", he adjusts his visual perception.

According to Ostwald [14] harmony of color is created according to the sequence and relation between the colors. He established a rule of harmonies = sequence, analyzing the sequences of colors using the rules of matching. In psychology, the method of sequence is used when it is not possible to measure the size of specific characteristic, but, based on direct comparisons, for each member we can determine its relative position among others.

For each position of the color the observer gave the number of that position (he ranked them), according to his sequence of watching-perception, from 1 to 8, depending on

Table 1 The standard deviation for each position of the yellow on the background color

Color on the background	the values of standard deviation (*sd*)/position of yellow samples 1	2	3	4	5	6	7	8
White	0,49	0,33						
Black				0,52	0,43			
Gray	0,53	0,50		0,44	0,44			
Yellow			0,24	0,40	0,54	0,21		
Blue				0,50	0,50	1,43	1,33	

the background color.

The aim of the statistical analysis of the quantitative data is to enable as correct as possible a description of the examinees' answers. The standard deviation in the mathematical sense demonstrates the scatter of results, Tab. 1.

Experience of each position of the color is ranked for each background color as a color of the environment, according to the psychological attribute of color; lightness – *L* and chrome – *C* as referent stimuli, and all that on the achromatic backgrounds and chromatic backgrounds.

Under the value of the lightness of some color is understood the extent to which the color (of the same tone) is bright or dark, respectively similar to the white or black, and psychological experience will depend on the overall intensity of the light of color of the environment (background) and color of the sample. Therefore, the lightness is often equated with the amount of energy of the light reflected from some object.

* *Experience of the position – ranking – of the samples on the achromatic background*

On achromatic background which provides a simple scale that goes from black through grey to white (scale evaluation of lightness from 0-black to 100-white), all other color tones are, by lightness, in their limiting values.

In general we can speak about the effect of achromatic induction based on the difference in lightness *L* between the background and positions of the color on the background.

On a white background we observed shifts of position for the yellow. Yellow color in the position 5, according to the ranking of observers, respectively adjustment, is placed at position 4, a higher lightness.

Standard deviation is in the correlation with the ranking of the position of color of the samples according to the brightness. It is confirmed that the largest value of standard deviation (discrepancy) on a *white background* was obtained at positions 5, 6 and 7, and it numbers from 0,52 to 1,37. Namely, yellow and white have maximum brightness, the consequence of what is that the observer has a problem to distinguish them. That was already assumed on the basis of the results of objective evaluation of the value of *L**.

On a *black background* there is maximum absorption of light, and, according to the theoretical consideration, the color becomes brighter, what is especially intense with the yellow color that has a high lightness of its own, so the observers easily replaced positions 4 and 5.

On a *grey background* samples were sorted -ranked- according to the background, with minor deviations. The obtained values of standard deviations confirm that we can expect larger uncertainty in the estimation of the rankings at positions 5 and 6 (*sd* = 0,83).

It should be noted that the grey background of the color is on the level of lightness *L**= 50, according to the CIE values, and it fits to medium grey what in the eye of the observer generates a state of complete equilibrium. Selected grey background did not influence the experience of the position, ranking of these colors.

* *Experience of the position – ranking – of the samples on the chromatic background*

These studies are based on the difference between the chromatic pairs of complementary colors, yellow-blue colors on the same background colors, and, according to the lightness of their own color, samples of the same color are ranked according to the assigned position. The result was that all examiners ranked the yellow color on a yellow background, according to the lightness, to the set positions. It was confirmed that the uncertainty of the evaluation of the position of the color in the eye of observer is more pronounced in the area in which the color retains a maximum purity of the saturation with the same tone, and they are correlated with the objective evaluation. It is confirmed that the intensity of yellow color darkens the blue tone of the background. The value of the relative standard deviation of 1,24 at the position of yellow on a blue background confirms that the blue background induces (increases) the yellow stimulus, which is located on its surface and hinders the resolution of the position.

* *Statistical data analysis of the visual assessment*

In the statistical analysis we used the methods of descriptive statistics and methods of statistical inference about differences in distributions between groups. For the testing of the hypothesis about the existence of statistically significant differences in color perception, error in the dependence to the background color (color of the environment), the appropriate non-parametric statistical tests were used: Mann-Whitnney U test, Kruskal-Wallis and Median test. The obtained values for the colors parameters, their lightness and saturation, show the difference between the experienced position of the sample and the actual position, depending on the color of the environment.

Figs. 4 and 5 show the psychological experience (frequency) of the observer for the position of the yellow color depending on the background and also on the saturation (*C*) and lightness (*L*). Position 1 (the smallest color saturation) on the white and black backgrounds demonstrated a substantial frequency mistake regarding the saturation experience.

That confirms that a great lightness of the white background, with a yellow tone which possesses a great lightness on its own, has a negative influence on the frequency of the tone position experience. On a grey background, a substantial scatter is present on all the positions. It is thought that the grey background, which has the same share of colors of all wave lengths, adds itself to the sample color, especially with larger chromacities, position 6, and the experience is "confusing" for the observer, Fig. 4. But it is also proved that the tone's own lightness has a considerable influence on the psychological experience of a tone.

So, for example, the yellow color, Fig. 5, position 4 (*L**=63, *C**=70) and position 5 (*L**=60, *C**=74), maintains even with big saturation with its own tone a large lightness

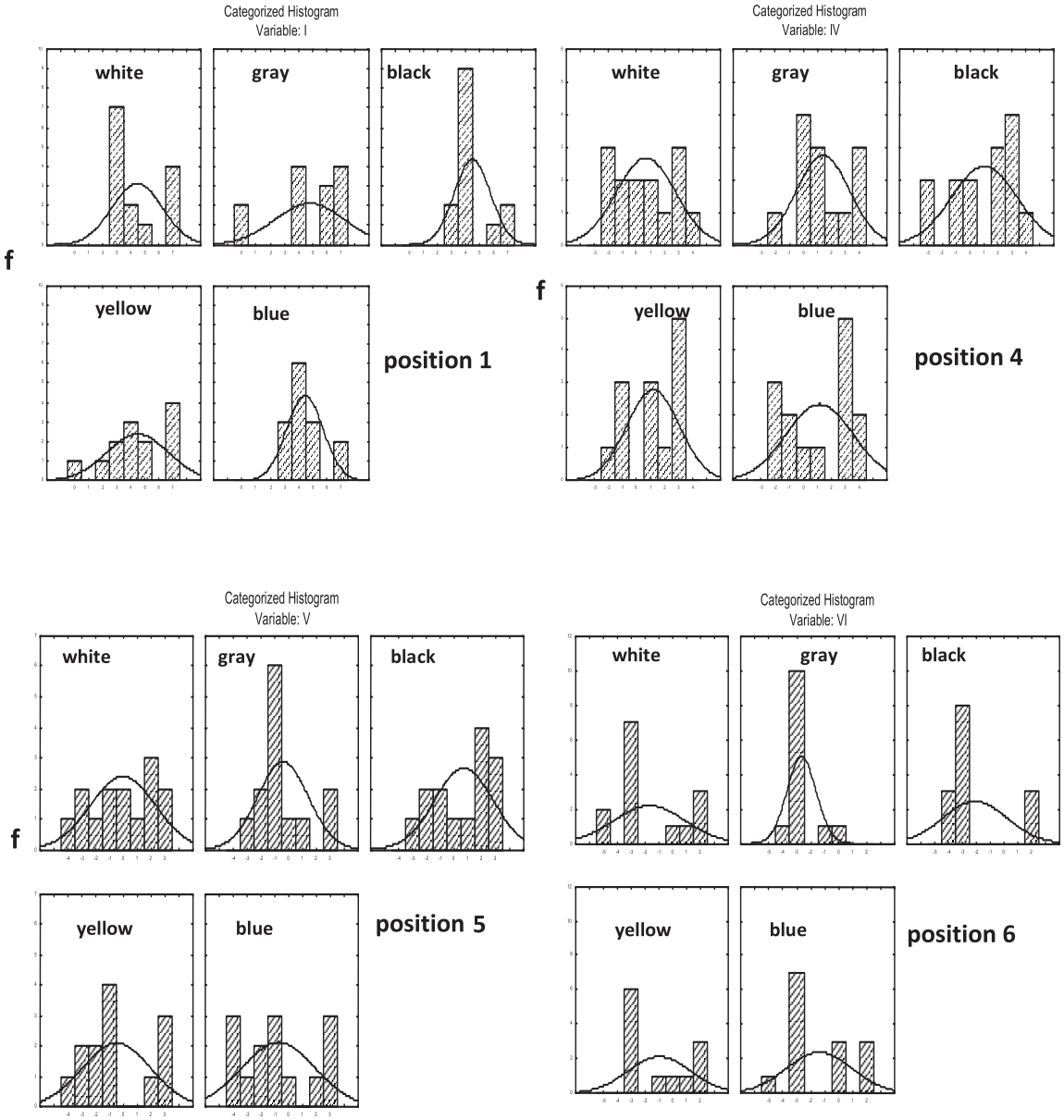

Figure 4 The psychological experience (frequency - *f*) of the observer regarding the saturation (*C*) for the position of the yellow color depending on the background

and on every background, this color tone will be psychologically experienced as intensive, often "confusing". The differences are not statistically important, especially on position 6.

Such an analysis contributes to the fact that in a work environment, it is recommended to avoid yellow tones, as they disturb the harmony of the colors and the environment, which is very important for obtaining work results.

4
Conclusion

It is proven that the threshold of visual perception can be determined with an objective spectro-photometric method, and it is correlated with the spectral characteristics of yellow tone.

On the threshold, the visual perception influences the way the questions are given to the observer. The method of ranking is considered to be the simplest, because the examinee himself interactively controls the value of stimuli, and can adjust his own visual perception.

A more complete answer on the influence of the background to the color experience is gained by the statistical analysis of the results obtained from the observer's evaluation of the relation of the color tone and background. On a black background with a slight light reflection, the psychological experience of colors possessing a great lightness and tone saturation with their own tone, as is the yellow color, depends on the "interpretation" of the observer (often an unsure evaluation).

Standard deviation is in the correlation with the ranking of the position of the color of the samples according to brightness. It is confirmed that the yellow on a *white background* presents a problem to the observer to distinguish it. Namely, yellow and white have a maximum brightness, what was already assumed on the basis of the results of objective evaluation of the value of L^*. On a *black background* with a slight light reflection, the psychological experience of colors possessing a great lightness and tone saturation with their own tone, as the yellow color, depends on the "interpretation" of the observer (often an unsure

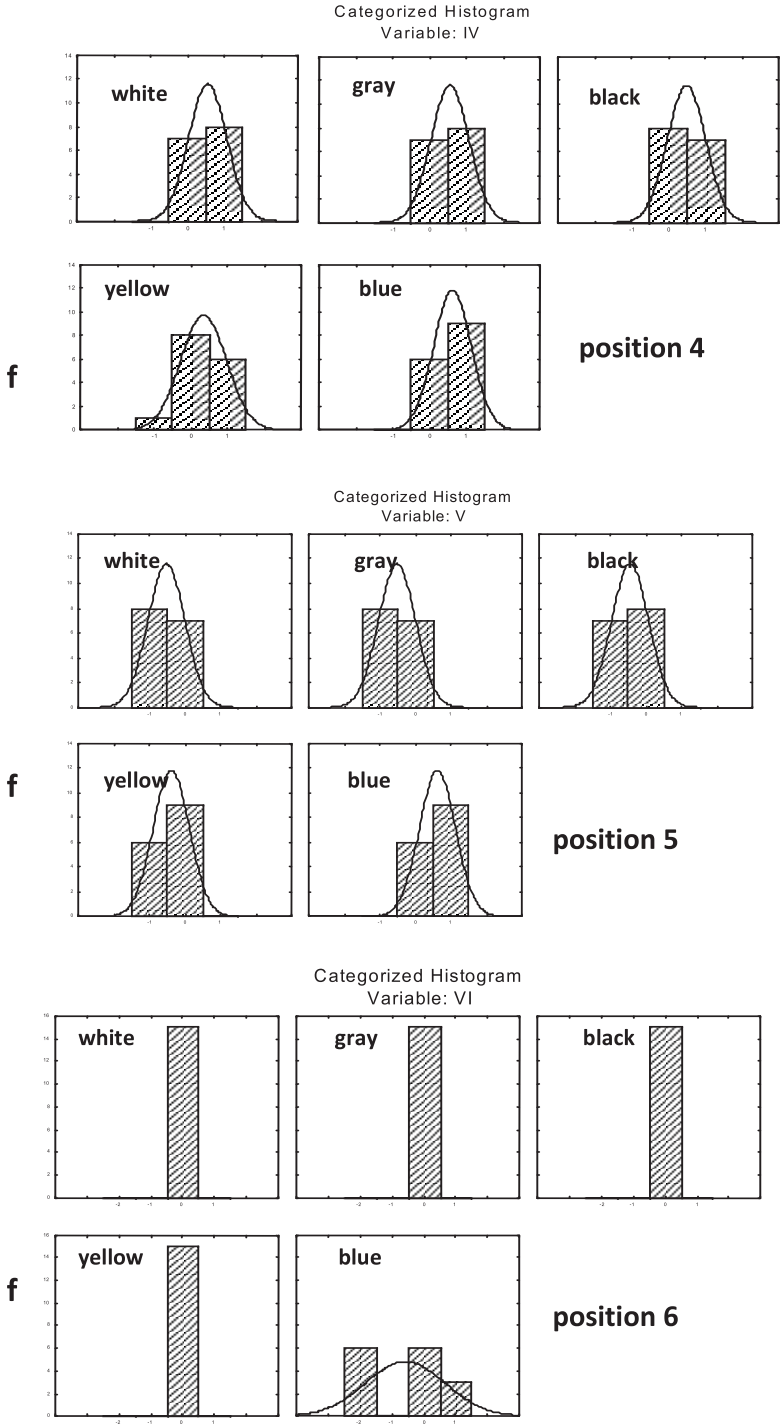

Figure 5 The psychological experience (frequency - *f*) of the observer regarding the lightness (*L*) for the position of the yellow color depending on the background

evaluation).

The value of the relative standard deviation of 1,43 at the position of yellow on a blue background confirms that the blue background induces (increases) the yellow stimulus which is located on its surface, and hinders the resolution of the position of the samples.

The conduced tests, targeted on the hypothesis about the existence of statistically significant differences in color perception, confirm, with the appropriate descriptive statistical tests, the error in the dependence to the background color (color of the environment).

It is recommended to avoid yellow tones, as they disturb the harmony of the colors and the environment, which is very important for obtaining good work results.

5
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