ISSN 1330-3651
UDC/UDK 655.2:535.645

INTENSITY EVALUATION OF THE SPREADING AND SIMULTANEOUS CONTRAST EFFECTS BASED ON THE DOTTED WHITE'S SAMPLES

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Original scientific paper
Systems and methods of visual communication, which the processes of graphic reproduction are based on, are developed on a daily basis with new ideas related to the research results of certain psychophysical visual effects. Consequently, modern trends in this area are directed towards determining the difference in the quality of graphic reproductions in case of events of different psychophysical visual effects. This paper presents a conducted research of the influence of visual effects of spreading and simultaneous contrast which cause shift in the colour appearance (different combinations of primary colours of additive and subtractive synthesis) of the stimulus in the White's effect (Groundal dotted illusion) on the test patterns printed by using four standard methods of rendering. The evaluation was conducted using visual assessment technique, simultaneous binocular teaming.

Keywords: *colour, simultaneous contrast, spreading, rendering, White's effect*

Procjena intenziteta efekta rasprostiranja i simultanog kontrasta temeljenih na White-ovom točkastom uzorku

Izvorni znanstveni članak
Sustavi i metode vizualne komunikacije na kojima se baziraju procesi grafičke reprodukcije svakodnevno se unapređuju s novim saznanjima vezanima uz rezultate istraživanja pojedinih psihofizikalnih vizualnih efekata. U skladu s time suvremeni trendovi ovog područja usmjereni su prema određivanju razlike u kvaliteti grafičkih reprodukcija u slučaju manifestacije različitih psihofizikalnih efekata. U radu je provedeno istraživanje utjecaja vizualnih efekata rasprostiranja i simultanog kontrasta koji izazivaju pomak pojavnosti boje (različite kombinacija primarnih boja aditivne i suptraktivne sinteze) stimulusa na White-ovom efektu (Groundalov točkasti efekt) na testnim uzorcima otisnutim koristeći četiri standardne metode renderiranja. Procjena je provedena primjenom vizualne tehnike ocjenjivanja, simultanog dvoglednog usuglašavanja.

Ključne riječi: *boja, rasprostiranje, renderiranje, simultani kontrast, White-ov točkasti uzorak*

1 Introduction

Different theories which describe the White's effect are mainly based on spatial frequency filtering [1, 2, 3], geometric and photometric signs [4, 5), the light-model statistics [6], the contrast-contrast illusion [7], the Gestalt grouping [8, 9, 10], and on T-junctions [11].

Avoiding the influence of T-junctions has led to the appearance of the dotted version of the White's effect [12]. The same effect connects psychophysical effects of simultaneous contrast and spreading. Colour, spreading and simultaneous contrast are among the parameters that largely determine the quality parameters in the process of graphic reproduction, or the perception of the finished graphic product quality. In general, perception is always determined by the context in which it is placed. Perceived colour depends on the spectral distribution of the stimulus, its structure, size, shape, surface characteristics of the object from which the stimulus originates, the complexity (in the case of image files) and the background and environment in which the stimulus is observed, on the entrance angle of the stimulus, adaptive state of observer's visual system, attention, etc. [13, 14, 15, 16].

Simultaneous contrast is a psychophysical visual effect that causes a shift in colour appearance, and is caused by the change of background colour. Since we very rarely see a specific colour isolated, simultaneous contrast effect size varies depending on the colour, saturation of the substrate and the contrast itself [17, 18, 19, 20, 21, 22]. In principle, light background causes a darker colour perception of the observed coloured stimulus.

Spreading is a psychophysical visual effect of apparent mixing of coloured stimulus with its background. The effect is considered complete when the width of the visual field and the distance between the observer and the observed surface is such that there is merging [23, 24].

The spreading effect is the fundamental psychophysical visual effect that the overall graphic technology is based on, since all the techniques of rastering are based on it. When the frequency of a given identical stimulus appearance is increased on the spatial structure (visual field) of the background that is observed, or when the stimulus with its size (or shape) becomes smaller, simultaneous contrast is slowly lost and replaced by the visual effect of spreading [25, 26, 27].

The purpose of this paper is to research and describe how and to what extent the mentioned effects influence colour perception and the qualitative characteristics of a finished graphic product. Since graphic designers are increasingly sought to create an original design, and accordingly, since psychophysical effects are increasingly used in designing different graphic products, the associated results of this study could be of help when describing and standardizing certain connected processes of graphic reproduction.

2 Experimental part

In order to study the influence of psychophysical visual effects of spreading and simultaneous contrast, and to describe how these effects influence colour perception, the dotted White's effect is determined.

By using experimental research, the purpose is to determine the influence that these effects, which cause a shift in the background colour appearance with different combinations of primary colours of additive and subtractive synthesis, have on colour perception, or the influence of the aforementioned on the qualitative characteristics of final graphic product.

The effects of spreading and simultaneous contrast will be observed on the middle (inner) squares of the White's effect (Fig. 1).

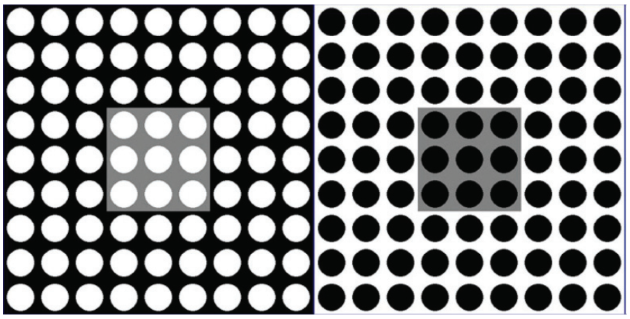

Figure 1 Dotted White's sample

The experimental part consists of two parts – instrumental and visual. The instrumental part includes spectrometric measurement, the description of the CIE $L^*a^*b^*$ values and calculation of the differences of colorimetric values of certain fields defined as relevant by a visual experiment in relation to the fields in the defined colour atlas.

For the visual part, the method of simultaneous binocular teaming was used [28]. This research provides the knowledge upgrade that will enable the prediction of colour appearance in the changing real conditions of graphic production with objective colour models [29]. Deviation in colour perception caused by a particular manifestation of a visual effect can be represented by colorimetric colour difference ΔE_{00} assigning a reference sample from the colour atlas to the tested sample [30, 31].

Colour difference (ΔE) in the Lab colour area is originally determined by the formula [23]:

$$\Delta E^*_{ab} = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

$$\Delta L^* = L_0 - L_1$$

$$\Delta a^* = a_0 - a_1$$

$$\Delta b^* = b_0 - b_1$$

where L_0, a_0, b_0 are physical values of perceived test pattern colour, and L_1, a_1, b_1 represent the physical value of the reference colour.

Colour difference expressed as ΔE_{00} is based on the formula ΔE_{94}, but apart from lightness (L), chroma (C) and hue (H), it includes hue and chroma differences and factor of value increase, all in order to improve defining the colour difference in the blue part of spectrum and achromatic colours difference. Colour difference ΔE_{00} is calculated by the formula [23]:

$$\Delta E_{00} = \left[\left(\frac{\Delta L'}{k_L S_L} \right)^2 + \left(\frac{\Delta C'_{ab}}{k_C S_C} \right)^2 + \left(\frac{\Delta H'_{ab}}{k_H S_H} \right)^2 + R_T \left(\frac{\Delta C'_{ab}}{k_C S_C} \right) \cdot \left(\frac{\Delta H'_{ab}}{k_H S_H} \right) \right]^{0,5}$$

$$L' = L^*$$

$$a' = (1 + G) \cdot a^*$$

$$b' = b^*$$

$$C'_{ab} = \left[(a')^2 + (b')^2 \right]^{0,5}$$

$$h' = \tan^{-1}\left(\frac{b'}{a'} \right)$$

$$G = 0,5 \cdot \left\{ 1 - \left[\frac{(\bar{C}^*_{ab})^7}{(\bar{C}^*_{ab})^7 + 25^7} \right]^{0,5} \right\}$$

where $\bar{C}^*_{ab}$ is the arithmetic mean of the value C'_{ab} of the observed samples

$$\Delta L' = L'_b - L'_s$$

$$\Delta C'_{ab} = C'_{ab,b} - C'_{ab,s}$$

$$\Delta H'_{ab} = 2(C'_{ab,b} C'_{ab,s})^{0,5} \cdot \sin\left(\frac{\Delta h'_{ab}}{2} \right)$$

where

$$\Delta h'_{ab} = h'_{ab,b} - h'_{ab,s}$$

$$S_L = 1 + \frac{0,015(\bar{L}' - 50)^2}{\left[20 + (\bar{L}' - 50)^2 \right]^{0,5}}$$

$$S_C = 1 + 0,045 \cdot \bar{C}'_{ab}$$

$$S_H = 1 + 0,015 \cdot \bar{C}'_{ab} \cdot T$$

where

$$T = 1 - 0,17 \cdot \cos(\bar{h}'_{ab} - 30°) + 0,24 \cdot \cos(2h'_{ab}) +$$
$$+ 0,32 \cdot \cos(3\bar{h}'_{ab} + 6°) - 0,20 \cdot \cos(4\bar{h}'_{ab} - 63°)$$

$$R_T = -\sin(2\Delta\Theta) \cdot R_C$$

where

$$\Delta\Theta = 30 \exp\left\{ -\left[\frac{\bar{h}'_{ab} - 275°}{25} \right]^2 \right\}$$

$$R_C = 2\left(\frac{(\bar{C}'_{ab})^7}{(\bar{C}'_{ab})^7 + 25^7} \right)^{0,5}.$$

Colour difference determined in this way enables the assessment of the differences (Tab. 1) [32].

Table 1 Assessment of the colorimetric colour difference for the standard observer

$\Delta E^* < 0,2$	no deviation is noted visually
$\Delta E^* = 0,2 \div 1$	small deviations are noted visually
$\Delta E^* = 1 \div 3$	acceptable visual deviation
$\Delta E^* = 3 \div 6$	still acceptable visual deviation
$\Delta E^* > 6$	unacceptable visual deviation

2.1
Test form design

In order to ensure the same conditions when creating test patterns and colour atlas, and fields needed for the calculation of the gamut size, all these elements are placed on the same test form (Fig. 2). The test form is created in Adobe Photoshop. For all the elements the entries were made in $L^*a^*b^*$ colour model.

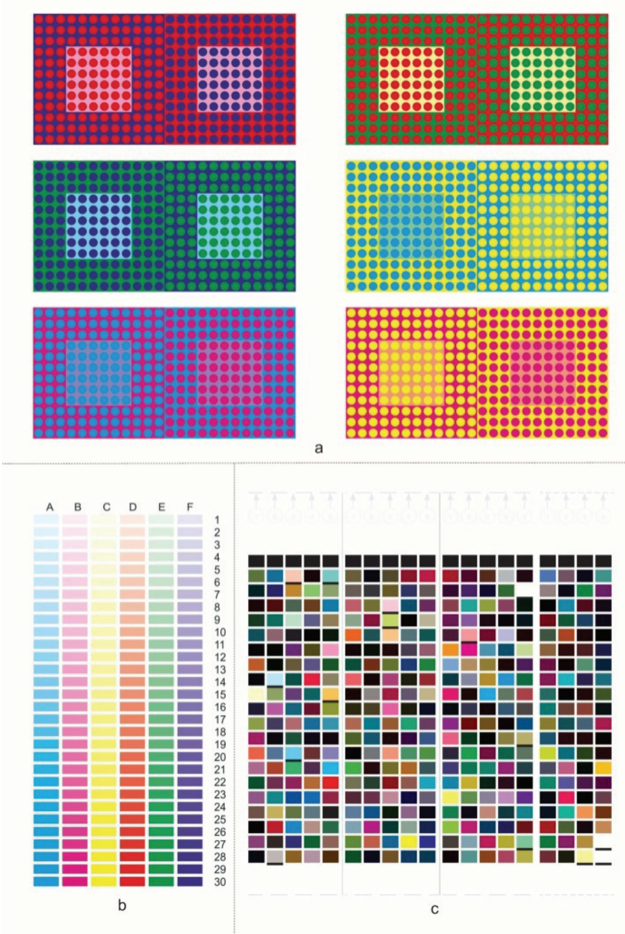

Figure 2 Test form

When creating test samples, the dotted White's effect (Fig. 1) was used as the basis point; it was modified in order to achieve the objectives of the research. The colours of some squares, backgrounds and dots were determined so that the study would cover all basic colours of additive and subtractive synthesis (Tab. 2 and Fig. 2a).

Table 2 The combination of colour pairs of test samples

Test sample	Colour of primary stimulus	Colour of secondary stimulus
1	magenta	red / blue
2	yellow	red / green
3	cyan	blue / green
4	green	cyan / yellow
5	blue	cyan / magenta
6	red	yellow / magenta

In this way, the determination of the effects of simultaneous contrast and spreading was enabled with basic colours of the graphic reproduction process, in relation to the influence of individual standard rendering method. The size of tested samples was determined in accordance with standard conditions of observation (ISO 3664:2009, which defines observing conditions for the graphic technology and professional photography), the viewing angle of 10°, and the participants' distance of 60 cm, which was obtained by the following formula [33]:

$$\tan\left(\frac{\theta}{2}\right)=\frac{H}{2},$$

where θ is the viewing angle, H is the test sample size.

For the evaluation of test samples the reference colour atlas with primary colours of additive and subtractive synthesis was made (Fig. 2b). The atlas is based on the change of the perception attributes within the Lab colour model. The atlas is designed so that it covers the complete potential area of certain colour perception. By spectrophotometric measurement, to certain samples in the colour atlas corresponding CIE $L^*a^*b^*$ values were defined. On the basis of certain samples from the atlas, which were associated with the CIE $L^*a^*b^*$ values, it is possible to determine the intensity of perception of spreading and simultaneous contrast effects.

For all test form variants, in addition to the test samples and the atlas, fields for calculating the gamut were also printed (Fig. 2c). All together, there are 4 test form variants printed (for each rendering) in the circulation of 10 copies.

2.2
Printing

The test form was printed on the calibrated machine for digital printing – Canon iPF6100 based on liquid toner using four standard methods of rendering. Rendering was done in Adobe Photoshop where it was moved from the Lab colour space to the colour space of the profile Canon iPF6100 Premium Matt Paper Highest. As the conversion option the Adobe (ACE) option was selected, and as a printing substrate Canon matt coated 7125 paper of grammage of 180 g/m^2 was used. Before printing, the paper was conditioned in a room for 48 hours in the prescribed standard ambient conditions (temperature of 23 °C and relative humidity of 55 %).

2.3
Instrumental analysis

Measurement of the samples from the instrumental analysis part was carried out with X-Rite DTP 41 spectrophotometer ranging in wavelength 390-710 nm of light source, a step of 10 nm and illumination geometry 45°/0°. In order to increase the statistical accuracy of instrumental analysis, the values of the control fields were measured on the circulation of 10 copies for each of the rendering methods. Each sample was measured twice, after which the average values were calculated. The accuracy of the device or the average deviation in terms of reflection amounts to 0,5 % per step of wavelengths. The standard for its calibration was moderated by the Munsell's Laboratory (RIT) with an accuracy of

ΔE^*=0,25 for the D50 light source and viewing angle of 2°. Based on the results of spectrophotometric measurements, after the conversion from CIE XYZ colour space (output data of X-Rite DTP41) in the CIE $L^*a^*b^*$ values, using the application ColorThink the gamut volumes of individual prints were calculated (Tab. 3).

Table 3 Gamut size of individual rendering methods for L^*=50 with corresponding calculated gamut volumes – expressed in CIE $L^*a^*b^*$ CCU

Rendering methods	Gamut volume (CIE $L^*a^*b^*$ CCU)
Perceptual	346,098
Saturation	351,167
Relative colorimetric	361,590
Absolute colorimetric	371,810

2.3 Visual analysis

Visual analysis of the test samples in the experimental research was performed on 20 participants of mixed population of average age 21 years. Prior to testing, all the participants had to meet the criteria of the Ishihara test which would check the potential sight deficiency. Only those who met the Ishihara test were able to participate in the research. Visual evaluation of psychophysical part of the experiment was carried out under controlled environmental conditions (ISO 3664:2009 – 10° viewing angle, 60 cm distance of participants from a test sample, natural matt gray environment, artificial lighting). That is why a stationary cabin for test samples "The Judge II-S" was used for visual assessment. Test samples were evaluated under the standard CIE lighting D50 (5000 K). For visual testing, the method of visual assessment will be used, that is simultaneous binocular teaming. Each participant will conduct visual assessment so that the colour atlas and test sample are simultaneously in the whole visual field (one next to the other). Their task will be to choose a field in the colour atlas which – according to their judgment – is the most similar or identical to the smaller squares on the test sample (Fig. 4). Time of testing was not limited.

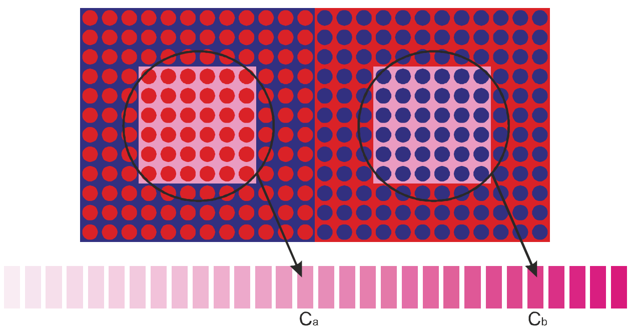

Figure 4 The principle of visual assessment using the colour atlas

The method described is a method of constant stimuli in which random samples of stimuli with different physical values are presented to participants. The values of physical stimulus (corresponding fields in the colour atlas) are determined so as to cover the entire area of the potential perception. By equating the reference field from the colour atlas with the expected colour manifested in the test sample also means joining the colorimetric values and calculating the specific colorimetric difference. In this way, a deviation in colour perception, which is due to the effects of simultaneous contrast and spreading, is obtained.

3 Results and conclusion

Based on research results obtained by the spectrophotometric measurement of reference fields of the colour atlas the corresponding CIE $L^*a^*b^*$ colorimetric differences of individual fields were determined. The same results were associated with the results of visual assessments, and for all test samples the colorimetric difference between ΔE_{00} colours was calculated.

Tabs. 4 ÷ 9 present the results of visual assessment of the White's effect created by primary colours of additive and subtractive synthesis, and observed under the standard CIE D50 lighting.

Tab. 4 presents the average values of results of visual assessment of the White's effect, created by magenta of the primary stimulus (inner square) in dependence with the red of the dots and blue (outer square) – left side, and the blue of dots and red (outer square) – right side of the secondary stimulus realized through four standard rendering methods.

Table 4 Average values of results of visual assessment (ΔE_{00}) for Test sample 1

Rendering method							
Perceptual		Saturation		Absolute colorimetric		Relative colorimetric	
left	right	left	right	left	right	left	right
5,00	6,42	4,67	5,84	4,70	5,90	5,76	6,18

In the visual perception of magenta of the primary stimulus (inner square) with red (colour of the dots) and blue (outer square) as the colours of secondary stimuli, the colorimetric difference through four standard rendering methods is the lowest in saturation, then in absolute colorimetric, perceptual, and finally in relative colorimetric. The biggest difference between all four renderings is 1,09. In magenta of the primary stimulus (inner square) with blue (colour of the dots) and red (outer square) as a colour of the secondary stimulus, the smallest colorimetric difference is in saturation rendering, then absolute colorimetric, relative colorimetric, and it is the highest in perceptual rendering. The biggest difference between all four renderings was 0,58. Visual deviation in magenta of the primary stimulus (inner square) is in combination with red (colour of the dots) and blue (outer square) as a secondary stimulus presented through the colorimetric difference ΔE_{00}. By looking at Tab. 1, visually acceptable deviation can still be seen; with the reversed combination, blue (colour of the dots) and red (outer square) as secondary stimuli there is an unacceptable visual deviation. If the colorimetric differences between the left and the right square are compared, the smallest of them is in relative colorimetric rendering 0,42, and the biggest in perceptual 1,42.

Tab. 5 presents the average values of visual assessment results of the White's effect created in the yellow of the primary stimulus (inner square) in dependence with the red of the dots and green (outer square) – left side, and with the green of the dots and red (outer square) – right side of the secondary stimulus realized through four standard methods of rendering.

Table 5 Average values of results of visual assessment (ΔE_{00}) for Test sample 2

Rendering method							
Perceptual		Saturation		Absolute colorimetric		Relative colorimetric	
left	right	left	right	left	right	left	right
4,02	3,34	4,13	3,21	4,45	3,85	4,81	3,73

In the visual perception of the yellow of the primary stimulus with red (colour of the dots) and green (outer square) as the colours of secondary stimulus, colorimetric difference through the four methods of rendering is the smallest in perception, then in saturation, absolute colorimetric and finally in relative colorimetric. The biggest difference between all four renderings is 0,79. In the yellow of the primary stimulus, and green (colour of the dots) and red (outer square) as the colours of the secondary stimuli, the smallest colorimetric difference is in saturation rendering, then in perceptual, absolute colorimetric, and finally in relative colorimetric. The biggest difference between all four renderings is 0,64. In the yellow of the primary stimulus in combination with red (colour of the dots) and green (outer square) as the colours of the secondary stimulus and in inverse combination the visual deviations shown by colorimetric colour difference is still acceptable. If the colorimetric differences between the left and the right square are compared, the smallest one is in absolute colorimetric rendering 0,60, and the biggest in relative colorimetric 1,08.

Tab. 6 presents the average values of visual assessment results of the White's effect created in the cyan of the primary stimulus (inner square) in dependence with the blue of the dots and green (outer square) – left side, and the green of dots and blue (outer square) – right side of the secondary stimulus realized through four standard methods of rendering.

Table 6 Average values of results of visual assessment ΔE_{00} for Test sample 3

Rendering method							
Perceptual		Saturation		Absolute colorimetric		Relative colorimetric	
left	right	left	right	left	right	left	right
4,75	3,50	6,40	3,97	5,41	4,86	4,57	3,20

In the visual perception of the cyan of the primary stimulus with blue (colour of the dots) and green (outer square) as the colours of secondary stimulus, colorimetric difference through the four methods of rendering is the smallest in relative colorimetric, then perception, absolute colorimetric, and finally in saturation. The biggest difference between all four renderings is 1,83. With the cyan of the primary stimulus, and green (colour of the dots) and blue (outer square) as the colours of the secondary stimuli, the smallest colorimetric difference is in relative colorimetric rendering, then in perceptual, saturation, and finally in absolute colorimetric. The biggest difference between all four renderings is 1,66. In the cyan of the primary stimulus in combination with red (colour of the dots) and green (outer square) as the colours of the secondary stimulus, visual deviation shown by colorimetric colour difference is still acceptable while in the combination of green (colour of the dots) and red (outer square) in three renderings there is still visually acceptable deviation. In saturation rendering, there is unacceptable visual deviation. If the colorimetric differences between the left and the right square are compared, the smallest one is in absolute colorimetric rendering 0,55, and the biggest in saturation rendering 2,43.

Tab. 7 presents the average values of visual evaluation results of the White's effect created in the green of the primary stimulus (inner square) in dependence with the cyan of the dots and yellow (outer square) – left side, and the yellow of dots and cyan (outer square) – right side of the secondary stimulus realized through four standard methods of rendering.

Table 7 Average values of results of visual assessment ΔE_{00} for Test sample 4

Rendering method							
Perceptual		Saturation		Absolute colorimetric		Relative colorimetric	
left	right	left	right	left	right	left	right
9,31	6,64	9,11	6,51	9,38	5,82	8,66	6,30

In the visual perception of the green of the primary stimulus with cyan (colour of the dots) and yellow (outer square) as the colours of the secondary stimulus, colorimetric difference through the four methods of rendering is the smallest in relative colorimetric, then in saturation, perception, and finally in absolute colorimetric. The biggest difference between all four renderings is 0,72. In the green of the primary stimulus, and yellow (colour of the dots) and cyan (outer square) as the colours of the secondary stimuli, the smallest colorimetric difference is in absolute colorimetric rendering, then in relative colorimetric, saturation, and finally in perceptual. The biggest difference between all four renderings is 0,82. Visual deviation in the green of the primary stimulus with cyan (colour of the dots) and yellow (outer square) and inverse in yellow (colour of the dots) and cyan (outer square) as the colours of the secondary stimulus shown through colorimetric difference is visually unacceptable with the exception of yellow (colour of the dots) and cyan (outer square) as the colours of the secondary stimulus with absolute colorimetric rendering there is still acceptable visual deviation. If the colorimetric differences between the left and the right square are compared, the smallest one is in saturation rendering 2,60, and the biggest in absolute colorimetric rendering 3,56.

Tab. 8 presents the average values of visual evaluation results of White's effect created in the blue of the primary stimulus (inner square) in dependence with the cyan of the dots and magenta (outer square) – left side, and the magenta of dots and cyan (outer square) –

right side of the secondary stimulus realized through four standard methods of rendering.

Table 8 Average values of results of visual assessment ΔE_{00} for Test sample 5

Rendering method							
Perceptual		Saturation		Absolute colorimetric		Relative colorimetric	
left	right	left	right	left	right	left	right
4,24	9,42	4,80	9,92	5,84	11,50	4,84	10,55

In the visual perception of the blue of the primary stimulus with cyan (colour of the dots) and magenta (outer square) as the colours of the secondary stimulus, colorimetric difference through the four methods of rendering is the smallest in perception, then in saturation, relative colorimetric, and finally in absolute colorimetric. The biggest difference between all four renderings is 1,6. With the blue of the primary stimulus, and green (colour of the dots) and cyan (outer square) as the colours of the secondary stimuli, the smallest colorimetric difference is in perceptual rendering, then in relative colorimetric, saturation, and finally in absolute colorimetric. The biggest difference between all four renderings is 2,08. Visual deviation of the blue of the primary stimulus with cyan (colour of the dots) and green (outer square) as the colours of the secondary stimuli shown through colorimetric difference is still acceptable, and unacceptable in saturation and absolute colorimetric rendering. Visual deviation of blue of the primary stimulus with green (colour of the dots) and cyan (outer square) as the colours of the secondary stimuli shown through colorimetric difference is unacceptable. If the colorimetric differences between the left and the right square are compared, the smallest one is in saturation rendering 5,12, and the biggest in relative colorimetric rendering 5,71.

Tab. 9 presents the average values of visual evaluation results of the White's effect created in the red of the primary stimulus (inner square) in dependence with the yellow of the dots and magenta (outer square) – left side, and the magenta of the dots and yellow (outer square) – right side of the secondary stimulus realized through four standard methods of rendering.

Table 9 Average values of results of visual assessment ΔE_{00} for Test sample 6

Rendering method							
Perceptual		Saturation		Absolute colorimetric		Relative colorimetric	
left	right	left	right	left	right	left	right
6,23	10,76	7,55	11,72	6,37	10,80	7,14	10,36

In the visual perception of the red of the primary stimulus with yellow (colour of the dots) and magenta (outer square) as the colours of the secondary stimulus, colorimetric difference through the four methods of rendering is the smallest in perception, then in absolute colorimetric, relative colorimetric, and finally in saturation. The biggest difference between all four renderings is 1,32. With the blue of the primary stimulus, and magenta (colour of the dots) and yellow (outer square) as the colours of the secondary stimuli, the smallest colorimetric difference is in relative colorimetric rendering, then in perceptual, absolute colorimetric, and finally in saturation. The biggest difference between all four renderings is 1,36. Visual deviation of the red of the primary stimulus with yellow (colour of the dots) and magenta (outer square) as the colours of the secondary stimulus and in inverse combination visual deviation shown through colorimetric difference is unacceptable. If the colorimetric differences between the left and the right square are compared, the smallest is in relative colorimetric rendering 3,22, and the biggest in perceptual rendering 4,53.

4 Conclusion

By using experimental research, the influence of psychophysical visual effects of spreading and simultaneous contrast has been studied. To explore the influence and to describe how these effects influence the colour perception the dotted White's effect was determined. The results indicate how and to what extent these effects influence the colour perception, and the qualitative characteristics of the finished graphic product. Since graphic designers are increasingly sought to create an original design, and accordingly, since psychophysical effects are increasingly used in designing different graphic products, the associated results of this study could be of help when describing and standardizing certain processes of graphic reproduction which are connected with the aforementioned.

The results show that the intensity of the effects varies for different pairs of colours. By combining the influence of the psychophysical effects of spreading and simultaneous contrast with the colorimetric colour difference (ΔE_{00}) we can conclude that the influence is the smallest when the primary stimulus is coloured in primary colours of subtractive synthesis (yellow, cyan, magenta).

Although ΔE_{00} more precisely defines the colour difference than ΔE_{94}, in the blue part of the spectrum the perception of the primary stimulus coloured in blue is still the worst. Thus the intensity of the spreading effect and simultaneous contrast is the highest, which can be attributed to a lesser amount of receptors that are sensitive in this part of the spectrum. With yellow it is the weakest and that can be attributed to the brightness component of the colour itself.

It is also obvious that to a smaller extent rendering methods influence visual perception; the size of the intensity of the effects of simultaneous contrast and spreading is more influenced by the selection of colour combinations than by the gamut volume. This is confirmed by the obtained colorimetric differences between certain rendering methods.

In order to provide even more of the necessary knowledge regarding the influence of different psychophysical effects on the perception of the quality of the final graphic product additional related research on the influence of psychophysical effects is planned, everything to make a better description and standardization of certain processes of graphic reproduction.

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