The appearance of the visual effect simultaneous contrast depending on the printing substrate

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Abstract

The paper presents the results of the comparison of the achromatic simultaneous contrast effect on two different printing substrates. The presented samples contain 10 different variations of background lightness and have a value range from 10 to 100% RTV in increments of 10% RTV (external square) that surrounds the primary stimulus (internal square) of the constant lightness of 50% RTV on a specifically constructed design. In the psychophysical visual experiment conducted on ten subjects for each sample, the intensity and direction of the variation of the occurrence of lightness in the CIEΔE00 system has been determined. The verified technique of simultaneous binocular harmonization was used. The results of the statistical analysis give the direction and intensity of the effect on a coated and uncoated substrate. The conducted Student's t-test of the comparison of arithmetic means of lightness variations clearly shows that the effect of simultaneous contrast is more strongly manifested on an uncoated substrate on samples with 10%, 20%, 40%, 50%, 90% and 100% of the RTV of the background ($p<0.05$). On samples with 30%, 60%, 70% and 80% of the RTV of the background, there are no statistically significant differences between the samples ($p<0.05$).

Keywords: Achromatic reproduction, coated and uncoated substrate, simultaneous contrast, Student's t-test

1. Introduction

Today, with the appearance of ever more demanding design solutions in the contemporary multimedia environment, certain problems that occur during the transfer of such solutions in the cross media reproductive system are also appearing. The mentioned problems occur in the form of a shift in the manifestation of colors that are largely caused by the psychophysical visual effect of induction or simultaneous contrast, which are by their nature such that they cause a certain shift in the manifestation of the color of the presented stimulus (Lukaček et al. 2013).

Psychophysics is a scientific discipline with an interest in exploring the perceptual reaction, i.e. the experience caused by a particular stimulus (Milković et al. 2009). Accordingly, in graphic technology certain psychophysical methods examine the shift in the manifestation of color. The mentioned methodology is very often applied in cross-media communication systems, which gives the possibility of defining the optimal conditions for the application of the influencing parameters related to the design, reproduction, and creation of image files on graphic products in the circumstances of a potential manifestation of psychophysical visual effects (Milković et al. 2013). Cross-media communications are integrated and interactive experiences that occur within different media (Gescheider 1985). Namely, the shift in the manifestation of color is a common perceptual phenomenon that occurs at each image graphic reproduction. Moreover, Richard O. Brown and Donald I. A. MacLeod are of the opinion that none of the colors of the objects in the visual field is perceived separately from the colors of all other objects (Creutzfeldt & Ito 1968).

Simultaneous contrast occurs both with achromatic colors, due to the effect of simultaneous contrast if a gray sample is taken, and a white sample is put next to such gray sample, the color gray will look darker next to the white sample than the next to the black sample (Bressan

2001) and with chromatic color pairs. It has thus been determined that the effect of simultaneous contrast is more strongly manifested on objects with complementary colors (Rossotti 1985). If a primary stimulus with a specific RTV is taken and then surrounded with a secondary stimulus of different RTV (e.g. the primary stimulus of 40% RTV of the color black and secondary stimuli that surround it of 0%, 30%, 70%, and 100% RTV of the color black), the primary stimulus will with a lighter background be perceived as darker, while with a darker background, it will be perceived as brighter. In other words, a light background induces the experience of the primary stimulus so that it appears as darker, while a dark background induces an experience due to which the observed stimulus on such a background appears as brighter. Chromatic simultaneous contrast is based on localized chromatic adaptation (Brenner & Cornelissen 1991; Hong & Shevell 2004; Norton et al. 2002). Different mathematical models that enable the calculation of the intensity and direction of the effect of simultaneous contrast have been made, such as the retinex theory (Land & Mccann 1971) and the DOG and ODOG models (McArthur & Moulden 1999). The manifestations of this effect on graphic reproductions have also been examined, so as to achieve as an efficient control of information on color in a cross-media information system as possible (Matijević et al. 2014).

The goal of every visual psychophysical research is to identify and define in detail a perceptually determined response of the test subject induced by the stimulus of precisely defined physical characteristics that are instrumentally measurable (Devlin 2004; Wu et al. 2004). The intensity of the effect is displayed through the calculated colorimetric differences of colors (Wu et al. 2004). Psychophysical research primarily seeks to determine whether the respondent can detect a particular stimulus and compare it with another stimulus and describe the differences (Milković 2006). The paper presents the results of the research of the background psychophysical effect of induction or simultaneous contrast. The research determined the extent to which reproduced samples differ with respect to the predefined values of the color from the atlas, and what the difference in the perception of the same stimulus presented on different printing substrates is. On the basis of the obtained results, the strength of the psychophysical visual effect of induction or simultaneous contrast for different variations of background lightness on two different printing substrates has been shown.

2. Experimental part

In the experimental part of the research, a test sample that causes the manifestation of the effects of simultaneous contrast was made. The sample was created as an achromatic figure (stimulus) that causes the effect of simultaneous contrast, the internal field has a value of 50% RTV of the color black (primary stimulus), while the external fields which represent the background (secondary stimulus) have a value range from 0 - 100% RTV of the color black in increments of 10% RTV from left to right (Figure 1). The primary stimuli are on the press form deployed in such a way that the internal square is right above the separate zone of the ink tray, whereby the "empty" zone of the ink tray is located between the two stimuli in order to prevent the influence of neighboring zones on the inking. In that way, from the 23 available zones of the B2 format, every second zone is empty, while vertically the lines with the stimuli are propagated to the sheet range. Respondents (10) had the task to assign to the primary stimulus on the reproduction obtained according to the CIP3 values the fields from the color atlas that they perceived to be the most similar. Each respondent took the test 10 times, and what was measured was the arithmetic mean of the Lab values of the fields from the color atlas that were assigned to the referential primary stimulus and that were taken into account in further measurements.

Printing was carried out on a calibrated machine for offset printing on two types of printing substrates, on a coated and uncoated printing substrate. Kundstruck paper with a thickness of 140g/m^2 was used as a coated printing substrate, while the wood-free offset paper with a thickness of 140g/m^2 was used as an uncoated printing substrate. The ambient condition of the space for visual evaluation was compliant with the guidelines of the ISO 3664: 2009 norm (10° viewing angle, 60 cm the distance of respondents from the test sample, natural matt gray environment). The evaluation of the effect, i.e. the tuning of test samples, was conducted on a sample of 10 respondents, the average age of 23 years. The test form was printed on a calibrated machine for offset printing – Heidelberg Speedmaster SM 74-5-P by using the perceptual ICC rendering method. Rendering was done in Adobe Photoshop, where a transition from the Lab space of colors into the space of the colors of the profile for offset printing occurred. The Adobe (ACE) option was selected as a conversion option, and the two previously mentioned types of paper were used as a printing substrate. Before printing, the paper was conditioned in operation for 48 hours in the stipulated standard ambient conditions (temperature of 23 °C and relative humidity of 55%). The color atlas was made on a machine for the production of match prints, Espon Stylus Pro 4880, which was calibrated according to the curves for the calibration of a printing machine. The atlas was printed on the same printing substrates on which the impressions were made. The offset plate with the test form was manufactured by Kodak, and the plate type is Electra XD (thermal positive plate), with a spectral sensitivity from 800 to 850 nm. The plate was made at a resolution of 175 lines and raster value of 2400 dpi (AM raster), and the format of the plate is 745 x 605 cm. The device on which the offset plate was made is the platesetter Magnus Q800 Platesetter manufactured by Kodak. After the printing process, the first step is the visual comparison of the color atlas which was printed on the calibrated device for the production of match prints with a reproduction obtained according to the CIP3 values. The values of the internal fields on the impression were measured with the help of a spectrophotometer X Rite I1 Pro and they were visually compared with the fields on the color atlas on which the fields are designed so that each field has an increase in value of 2.5% RTV compared to the previous field, starting with the first field on the atlas that has a value of 2.5% RTV to the last field that has a value of 100% RTV (Figure 2). The atlas was made on the mentioned device to obtain as accurate comparison with the impression as possible. Namely, in real terms in printing houses, such devices are used for impression simulation, and they give a very high accuracy between the reproduction obtained by printing on a printing press and the print obtained on the device for the production of match prints. With this type of atlas in the range of 2.5% RTV, what is obtained is a more accurate comparison at the impression – match print correlation than it is the case with the existing (standard) atlas (Munsell's) that does not have such a fineness of range between the fields. After the visual evaluation and association of the corresponding fields from the color atlas with the primary stimuli on the reproductions obtained according to the CIP3 values, the CIE Lab values on the atlas and the reproduction were measured. Furthermore, ΔL00 and ΔE00 were also calculated. After that, deviations of the obtained values of the test fields (stimuli) in relation to the CIP3 referential values (spectrophotometric analysis and conversion to CIE Lab) were calculated on the obtained samples.

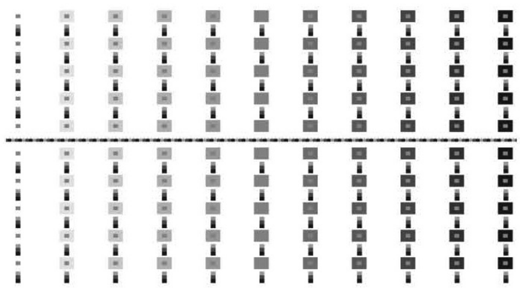


Figure 1. The design of the test form of the achromatic effect of simultaneous contrast

Figure 2. Color atlas with achromatic tones

The results of the research of Lab values were calculated with the help of the ΔE00 formula, where:

$$\Delta L' = L'_b - L'_s \quad (1)$$

$$\Delta C'_{ab} = C'_{ab,b} - C'_{ab,s} \quad (2)$$

$$\Delta H'ab = \left[2\left(C'_{ab,b}C'_{ab,s}\right)^{0.5} \sin\left(\frac{\Delta h'_{ab}}{2}\right) \right] \quad (3)$$

$$\Delta E_{00} = \left[\left(\frac{\Delta L'}{k_L S_L}\right)^2 + \left(\frac{\Delta C'_{ab}}{k_C S_C}\right)^2 + \left(\frac{\Delta H'_{ab}}{k_H S_H}\right)^2 + R_T \left(\frac{\Delta C'_{ab}}{k_C S_C}\right)\left(\frac{\Delta H'_{ab}}{k_H S_H}\right) \right]^{0.5} \quad (4)$$

3. Research results

This chapter presents the results of the testing of the effect of achromatic simultaneous contrast on the primary stimulus of the lightness of 50% RTV, with different variations of the lightness of the secondary stimulus that surrounds the primary stimulus, and two different backgrounds. In that way, ten different samples on two different printing substrates (uncoated and coated) were obtained. The results of the descriptive statistics that was carried out on the results of the psychophysical visual experiment are also presented. To be more precise, the values of deviations in lightness between the perceived and the physical lightness of the primary stimulus, i.e. the values of the variable ΔL00 were analyzed. The mentioned statistical analysis was carried out in the program STATISTICA 12 (StatSoft, Tulsa, USA). The results of the research of Lab values were calculated with the help of the ΔE00 formula.

Because of the technical characteristics of the printing device, very small differences between the printed primary stimuli occurred ($\Delta L \leq 4$). Therefore, those differences did not influence the results of the experiment. Tables 1 and 2. show the Lab values of the referential primary stimuli for two different printing substrates.

Table 1. An overview of the referential Lab values of the primary stimulus on an uncoated substrate (internal squares)

Lightness (RTV)	L	a	b
10%	61.3	1.2	-3.9
20%	61.0	1.2	-3.9
30%	60.8	1.2	-3.9
40%	60.5	1.2	-3.9
50%	60.0	1.2	-3.9
60%	59.8	1.2	-3.9
70%	59.3	1.2	-3.9
80%	58.9	1.2	-3.9
90%	58.6	1.2	-3.8
100%	58.3	1.2	-3.8

Table 2. An overview of the referential Lab values of the primary stimulus on a coated substrate (internal squares)

Lightness (RTV)	L	a	b
10%	61.0	0.5	-3.3
20%	60.7	0.5	-3.3
30%	60.0	0.5	-3.3
40%	59.8	0.5	-3.3
50%	59.2	0.5	-3.3
60%	59.0	0,5	-3.3
70%	58.7	0.5	-3.3
80%	58.4	0.5	-3.3
90%	58.1	0.5	-3.3
100%	57.5	0.5	-3.3

Moreover, Tables 3 and 4. show the obtained values of colorimetric differences between the primary stimuli and the assigned fields from the color atlas for the effect of achromatic simultaneous contrast on two different printing substrates.

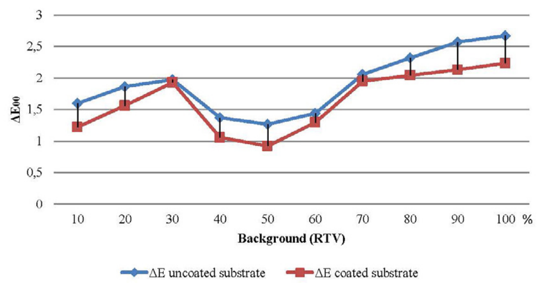
Table 3. An overview of the obtained values of colorimetric differences between the referential primary stimulus and the assigned fields from the color atlas on an uncoated printing substrate

Lightness (RTV)	ΔE_{00}	ΔL_{00}	ΔC_{00}	ΔH_{00}
10%	1.59	1.57	0.22	-0.12
20%	1.86	1.84	0.22	-0.12
30%	1.97	1.94	0.30	-0.17
40%	1.36	-1.29	0.37	-0.21
50%	1.26	-1.21	0.30	-0.17
60%	1.43	-1.39	0.30	-0.17
70%	2.05	-2.01	0.37	-0.21
80%	2.32	-2.28	0.37	-0.21
90%	2.57	-2.54	0.30	-0.17
100%	2.67	-2.64	0.36	-0.03

Table 4. An overview of the obtained values of colorimetric differences between the referential primary stimulus and the assigned fields from the color atlas on a coated printing substrate

Lightness (RTV)	ΔE_{00}	ΔL_{00}	ΔC_{00}	ΔH_{00}
10%	1.22	1.14	0.15	0.42
20%	1.56	1.50	0.15	0.42
30%	1.93	1.87	0.15	0.42
40%	1.06	-0.96	0.15	0.42
50%	0.92	-0.71	0.16	0.57
60%	1.30	-1.15	0.25	0.55
70%	1.95	-1.85	0.25	0.55
80%	2.04	-1.95	0.25	0.55
90%	2.13	-2.04	0.25	0.55
100%	2.23	-2.15	0.25	0.55

Figure 3. The ratio of the values of ΔE00 of the effect of achromatic simultaneous contrast on an uncoated and coated printing substrate



Namely, what can be seen on Figure 3 is the linearity between the measured values of ΔE00 on the two types of the printing substrate, whereby the deviation of ΔE00 when it comes to the effect of achromatic simultaneous contrast is a bit larger on the uncoated printing substrate than it is on the coated printing substrate. On both printing substrates, the values of ΔE00 increase on the primary stimuli with the background lightness of 10%, 20%, 30% RTV, while on the primary stimulus with the background lightness of 40% RTV, the value of ΔE00 begins to decrease. Moreover, on the primary stimulus with the background lightness of 50% RTV, it reaches its lowest value precisely due to the fact that the background is of the nearly identical value of the primary stimulus that is of 50% RTV of the color black. On the primary stimulus with the background lightness of 60% RTV, the value of ΔE00 begins to increase, and so it continues until the primary stimulus with the background lightness of 100% RTV, where it has its highest value, due to which the effect of simultaneous contrast is the most pronounced on the primary stimuli with background lightness of 70%, 80%, 90%, and 100% RTV.

The difference in the values of ΔE00 is the lowest on the primary stimuli with the background of 30% RTV, which on the uncoated substrate equals ΔE00 1.97, and on an uncoated substrate ΔE00 1.92. The biggest difference in the values of ΔE00 is on the primary stimulus with a background of 100% RTV, and on the uncoated substrate it equals ΔE00 2.67, while on the coated substrate it equals ΔE00 2.23.

The average value (arithmetic mean) of ΔE00 on an uncoated printing substrate at the achromatic simultaneous contrast effect equals ΔE00 1.91, while on the coated printing substrate it equals ΔE00 1.63.

Below are the results of the descriptive statistical analysis that was carried out on the results of the experiment, on both substrates, which is shown in the Tables 5 and 6.

Table 5. Descriptive statistics of the perceived difference in lightness (arithmetic mean±standard deviation (μ±σ), median (Med), minimum (Min), maximum (Max), variance (Var.)) on an uncoated substrate

Background lightness (RTV)	Descriptive statistics of differences in lightness				
	μ+/-σ	Med	Min	Max	Var.
10%	1.58±0.47	1.58	1.13	2.02	0.22
20%	1.85±0.60	1.85	1.23	2.48	0.36
30%	1.94±0.38	1.94	1.58	2.30	0.14
40%	-1.64±0.65	-1.47	-2.23	-0.87	0.30
50%	-1.22±0.36	-1.22	-1.56	-0.87	0.13
60%	-1.39±0.43	-1.39	-2.00	-0.79	0.19
70%	-2.01±0.54	-2.01	-2.52	-1.49	0.30
80%	-2.25±0.11	-2.28	-2.28	-1.94	0.01
90%	-2.55±0.52	-2.55	-3.23	-1.86	0.27
100%	-2.65±0.27	-2.65	-2.90	-2.39	0.07

It can be seen from Table 5 that the values of standard deviations and the variances of all observed samples are very small, which clearly indicates a high quality of the obtained results. Furthermore, the ranges between the minimum and maximum are very small.

Table 6. Descriptive statistics of the perceived difference in lightness (arithmetic mean±standard deviation (μ±σ), median (Med), minimum (Min), maximum (Max), variance (Var.)) on a coated substrate

Background lightness (RTV)	Descriptive statistics of differences in lightness				
	μ+/-σ	Med	Min	Max	Var.
10%	1.12±0.09	1.05	1.05	1.23	0.01
20%	1.36±0.05	1.36	1.32	1.41	0.00
30%	1.88±0.38	1.88	1.51	2.24	0.15
40%	-0.96±0.50	-0.96	-1.48	-0.44	0.25
50%	-0.84±0.21	-0.71	-1.15	-0.71	0.04
60%	-1.25±0.25	-1.41	-1.41	-0.89	0.06
70%	-1.75±0.13	-1.85	-1.85	-1.59	0.02
80%	-1.94±0.92	-1.94	-2.81	-1.07	0.84
90%	-2.11±0.36	-2.39	-2.39	-1.69	0.13
100%	-2.15±0.53	-2.15	-2.68	-1.62	0.28

The values of standard deviations and variances are also very small at all observed samples (Table 6). The ranges between the minimum and the maximum are also very small at all samples. The data clearly shows a high quality of the results of the psychophysical visual experiment.

4. Discussion of results

4.1 Kolmogorov-Smirnov test of the normality of samples

The compliance of all the obtained data with the law of normal distribution was verified. For that purpose, the Kolmogorov-Smirnov test was applied, and the results are shown in the Tables 7 and 8.

Table 7. Results of the Kolmogorov-Smirnov test (Max D statistics, empirical p-value) for an uncoated substrate

Lightness (RTV)	Max D	K-S p
10%	0.33	p < 0.20
20%	0.25	p > 0.20
30%	0.33	p < 0.20
40%	0.28	p > 0.20
50%	0.33	p < 0.20
60%	0.29	p > 0.20
70%	0.33	p < 0.20
80%	0.52	p < 0.01
90%	0.30	p > 0.20
100%	0.33	p < 0.20

The Kolmogorov-Smirnov test confirmed the compliance of almost all variables with the normal distribution (Table 7), with an exception of the result of the visual experiment at the background lightness of 80% RTV, where a deviation from the normal distribution law was determined.

Table 8. Results of the Kolmogorov-Smirnov test (Max D statistics, empirical p-value) for a coated substrate

Lightness (RTV)	Max D	K-S p
10%	0.38	p < 0.10
20%	0.33	p < 0.20
30%	0.33	p < 0.20
40%	0.25	p > 0.20
50%	0.43	p < 0.05
60%	0.43	p < 0.05
70%	0.38	p < 0.10
80%	0.33	p < 0.20
90%	0.38	p < 0.10
100%	0.25	p > 0.20

According to the results of the Kolmogorov-Smirnov test, almost all samples are in compliance with the normal distribution law (Table 8). The samples with background lightness of 50% RTV and 60% RTV slightly deviate from the normal distribution law.

4.2 Student's t-test

Below are the results of the conducted Student's t-test for dependent samples for the testing of the significance of differences between the arithmetic means of the sample pairs. The arithmetic means of samples were tested in relation to the corresponding background lightness. The test made sense considering the fact that almost all samples were in compliance with the normal distribution law.

Table 9. Results of the Student's t-test (contain the arithmetic means according to groups (AS 1, AS 2), the difference of arithmetic means (Diff.), the standard deviation of differences (St. dev. diff.), the value of the t-statistics (t), the number of freedom degrees (Df.), the p-value of the test (p)

Background lightness (RTV)	AS 1	AS 2	Diff.	St. Dev. Diff.	t	Df.	p
10%	1.58	1.12	0.46	0.48	3.03	9	0.01
20%	1.85	1.36	0.49	0.59	2.61	9	0.02
30%	1.94	1.88	0.07	0.59	0.37	9	0.72
40%	-1.64	-0.96	-0.67	0.60	-3.54	9	0.00
50%	-1.22	-0.84	-0.38	0.38	-3.17	9	0.01
60%	-1.39	-1.25	-0.14	0.57	-0.78	9	0.45
70%	-2.01	-1.75	-0.26	0.56	-1.46	9	0.17
80%	-2.25	-1.94	-0.30	0.89	-1.08	9	0.30
90%	-2.54	-2.11	-0.43	0.52	-2.65	9	0.02
100%	-2.65	-2.15	-0.50	0.64	-2.45	9	0.03

At all samples the arithmetic means in lightness are larger for uncoated than for coated samples. However, it has been determined that the arithmetic means that statistically significantly differ are those of the samples with 10%, 20%, 40%, 50%, 90%, and 100% RTV (Table 9), with the level of statistical significance of $p = 0.05$. At the samples with a background lightness of 30%, 60%, 70%, and 80% RTV, statistically significant differences cannot be determined.

5. Conclusion

The paper presents research results that show the intensity and direction of the shift in the manifestation of lightness that happens due to the manifestation of the background psychophysical visual effect of simultaneous contrast. The previously mentioned effect is manifested through the difference in the perception of the primary stimulus with regard to the change in the lightness of the secondary stimulus. The first part of the research shows a descriptive statistical analysis that was carried out on the results of the experiment obtained on both printing substrates, and it shows that the values of standard deviations and variants of all observed samples are very small. A further analysis with the help of the Kolmogorov-Smirnov test on an uncoated substrate, which confirmed the compliance of all samples with the normal distribution, except in the case of the results of the visual experiment with background lightness of 80% RTV, where a deviation from the normal distribution law was determined; while the results of the same test on an uncoated printing substrate determined that nearly all samples are in compliance with the normal distribution law, except for the samples with background lightness of 50% and 60% RTV, which slightly deviate from the normal distribution law. With the help of the Student's t-test it can be seen that with all the samples, the arithmetic means of the difference in lightness are larger for uncoated samples than for coated samples. However, it has been determined that the arithmetic means of samples with background lightness of 10%, 20%, 40%, 50%, 90%, and 100% RTV statistically significantly differ, with the level of statistical significance of $p = 0.05$. When it comes to the samples with background lightness of 30%, 60%, 70%, and 80% RTV, statistically significant differences cannot be determined. Accordingly, with the previously mentioned samples, the effect of achromatic simultaneous contrast is manifested nearly the same both with the uncoated and coated samples.

It can be seen from the presented results that lightness $\Delta L00$ on the primary stimuli with both printing substrates where lightness backgrounds are of 10%, 20%, and 30% RTV goes in one direction; while on the primary stimuli with background lightness of 40%, 50%, 60%, 70%, 80%, 90%, and 100% RTV it goes in the opposite direction. Namely, where the respondents perceived the darker fields from the color atlas in relation to the primary stimuli on the reproduction obtained according to the CIP3 values (backgrounds of 10%, 20%, and 30% RTV), on those stimuli lightness $\Delta L00$ goes in the positive direction, while on those primary stimuli where the respondents perceived the brighter fields from the color atlas, $\Delta L00$ goes in the negative direction

When it comes to the values of $\Delta E00$, they increase on fields with backgrounds of 10%, 20%, and 30% RTV, while on the primary stimulus with the background of 40% RTV, the value of $\Delta E00$ decreases, and on the primary stimuli with the background of 50% RTV, it decreases to the lowest value precisely due to the fact that the background is almost identical to the value of the primary stimulus that is 50% of the color black. On the primary stimulus with the background of 60% RTV, the value of $\Delta E00$ begins to increase, and it does so all the way to the primary stimulus where the background is of 100% RTV and it reaches its top value, and with it is the effect of simultaneous contrast the most pronounced in areas where backgrounds are of 60%, 70%, 80%, 90%, and 100% RTV. The difference is in the fact that the $\Delta E00$ values on an uncoated printing substrate with all fields on the primary stimulus relation obtained according to the CIP3 values and the arithmetic means of the assigned fields from the color atlas have somewhat larger values than the same fields on a coated printing substrate.

From the presented results, it can be seen that the psychophysical visual effect of simultaneous contrast is, in the case of the fixated primary stimulus with a value of 50% RTV of the color black, and when there is a change in the lightness of the secondary stimulus, perceived at certain places on an uncoated printing substrate more strongly than at the same places on a coated printing substrate.

References

1. Brenner, E. & Cornelissen F.W., 1991. Spatial interactions in color vision depend on distances between boundaries, Naturwissenschaften, 78.
2. Bressan, P., 2001. Explaining lightness illusions. // Perception. 30, pp. 1031-1046.
3. Creutzfeldt, O. & Ito, M., 1968. Functional synaptic organization of primary visual cortex neurones in the cat.Experimental Brain Research, 6, 324-352.
4. Devlin, A. K., 2004. „Perceptual fidelity for digital image display", ph.d. thesis, Faculty of Engineering, Department of Computer Science to the University of Bristol
5. Gescheider, G. A., 1985. Psychophysics, Method, Theory and Application, Erlbaum Associates, Hillsdale.

6. Hong, S. W. & Shevell, S. K., 2004. Brightness contrast and assimilation from patterned inducing backgrounds, Vision Research, 44, 35–43.
7. Land, E. H. & Mccann, J. J., 1971. Lightness and retinex theory. J. Opt. Soc. Amer. 61, 1-11.
8. Lukaček, M., et al., 2013. Analiza manifestacije McCollough efekta u Cross- Media reprodukcijskim sustavima, Tehnički glasnik vol. 7, 2, 170-176.
9. Matijević, M., et al., 2014. Efekt proširivanja i simultanog kontrasta kod modificiranih figural dotted i groundal dotted iluzija., Tehnički vjesnik 21, 6, 1297-1301.
10. McArthur, A. J. & Moulden, B., 1999. A two-dimensional model of brightness perception based on spatial filtering consistent with retinal processing, Vision Research, Volume 39, Issue 6, March, Pages 1199–1219.
11. Milković, M., 2006. Evaluacija odnosa psihofizikalnih determiniranih efekata i metoda prevođenja gamuta, doktorski rad, Zagreb
12. Milković, M. et al., 2012. Percepcija boje u cross-media komunikacijskim sustavima; Tiskarstvo i dizajn 27-34.
13. Milković, M. et al., 2009. „Vizualna psihofizika i dizajn“, Veleučilište u Varaždinu, Varaždin
14. Norton, T. T. et al., 2002. „The Psychophysical Measurement of Visual Function“, Butterworth-Heinemann, Woburn, Massachusetts
15. Rossotti, H., 1985. Colour: Why the World Isn't Grey, Princeton University Press, Princeton, NJ, pp 135-136.
16. Wu, R.C. et al., 2004. „A Comparison of Lightness Contrast Effects in CRT and Surface Colours“, Color Research and Application, Vol 30, 1, pp. 13-20.