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THE INFLUENCE OF STANDARD RENDERING METHODS ON THE MANIFESTED INTENSITY OF THE CHROMATIC INDUCTION EFFECT

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Original scientific paper

The focus of this work is directed to investigations with the aim of explaining the mutual relationships of parameters connected to the gamut size, rendering methods and the visual evaluations of the prints with the image presentations, which cause the psychophysical effect of the chromatic induction. The results of instrumental analysis in relation to the results of visual evaluation show aberration from the conventional point of view, according to which the increase of gamut size of prints is followed by the increase of the experience quality. In this sense the additional analyses are made and the correlations are determined which define the relationships of the previously mentioned parameters.

Key words: *chromatic induction, printed reproduction, methods of gamut transformation*

Utjecaj standardnih metoda renderiranja na ispoljenu jačinu kromatskog indukcijskog efekta

Izvorni znanstveni članak

Težište ovog rada je usmjereno na razjašnjavanje međusobnih odnosa parametara vezanih uz veličinu gamuta, metoda renderiranja te situacija kada se vizualno procjenjuju otisci sa slikovnim prikazima koji uzrokuju psihofizikalni efekt kromatske indukcije. Rezultati instrumentalne analize u odnosu na rezultate vizualnog ocjenjivanja pokazuju odstupanje od uvriježenog stajališta, prema kojem je povećanje veličine gamuta otisaka praćeno povećanjem u doživljaju kvalitete. U tom smislu napravljene su i dodatne analize te određene korelacije koje definiraju odnose prethodno navedenih parametara.

Ključne riječi: *kromatska indukcija, grafička reprodukcija, metode renderiranja*

1 Introduction
Uvod

It is desirable during each reproduction process to put all the parts of the reproduction chain into the existing standards if we wish the processes to develop with predictable result. In spite of all specific features it values for the process of producing the graphic reproduction. The contemporary market sets new demands every day and expects realization of reproductions with maximal quantities of information about colour and their compatibility with the original.

Manipulation with the physical characteristics of colour in the reproduction process of the contemporary graphic technology should not present greater problem. However, the problem can be expected in regard to the characteristics of colour connected to its psychophysical experience of colour.

Looking only from the physical point of view, the reproduction of greater gamut enables in principle more exact information transfer concerning the original colour and with this greater quality of the printed product. Compatible to that, there is the opinion that greater gamut means a priori greater experience of the reproduction quality. However, the intensity of the quality experience of some reproduction depends on some other parameters. Firstly on those connected with subjective physical colour experience and with the different psychophysical visual effects.

In this sense the focus of this work is directed to investigations with the aim of explaining the mutual relationships of parameters connected to the gamut size, rendering methods and the visual evaluations of the prints with the image presentations, which cause the psychophysical effect of the chromatic induction.

2 Theoretical part
Teorijski dio

Psychophysical visual effects are the psychophysically determined situations in which the classical colorimetric methods and their mathematical models are not able to foresee and to specify the experience of colour appearance at standard observer. Particular models of appearances such as: Guth 1995, LLAB 1996, RLAB 1996, Hunt 1994, Nayatani 1995, CAM 1997, have the possibility to specify exactly particular psychophysical visual effects (primarily the ambient-adaptation and the background ones). However, from the point of view of this work, it is important to stress that the mentioned models are not used in the process of transfer and mapping because of other characteristics.

Psychophysical visual effects can be divided into: ambient-adaptation visual effects, background visual effects, geometry-structural visual effects and other ones. From the point of view of this work the investigations were directed firstly towards the background visual effects.

2.1 Induction
Indukcija

Induction is the visual effect which causes the shift of colour appearance of some stimulus and it is caused firstly by the change of colour background. Induction as the appearance confirms in a way one of the theories of human perception and colour experience, that is the theory of contrary processes. If you look at Figure 1, you will notice that the basic stimulus (which is presented by smaller square and which is defined as the patch possessing the value of 30 % of dot percentage of black) is perceived differently with regard to the substrate characteristics (marked by the number from 1 – 4) on which the observed stimulus is placed, and which is presented by greater square. In other words, the bright background causes the increase of characteristics, it inducts some stimulus so that it looks darker, that is the dark background induces the experience (it increases the characteristics of the stimulus) on its surface which causes the observed stimulus to appear brighter.

Except for the previously described effect of *achromatic induction*, which is based on the difference in brightness between the background and the primary stimulus (application exclusively with achromatic colours), the relations among the achromatic pairs of colours which are caused by the physical visual effects called *chromatic induction* are known.

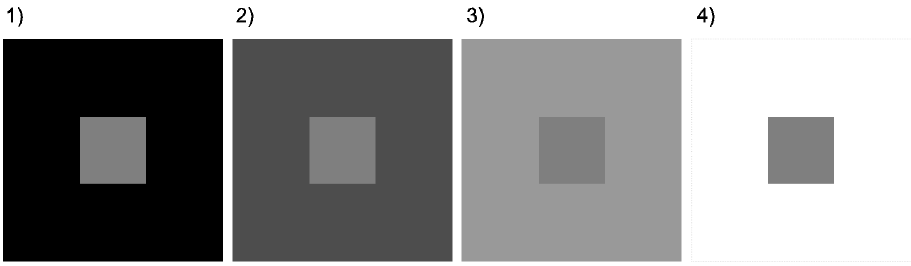


Figure 1. Demonstration of psychophysical visual effect of chromatic induction
Slika 1. Demonstracija psihofizikalnog vizualnog efekta kromatske indukcije

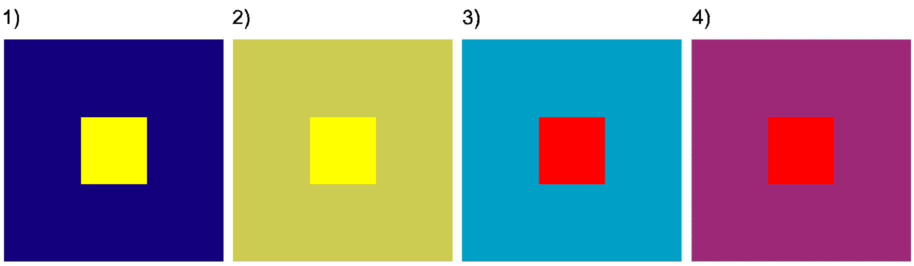


Figure 2. Demonstration of psychophysical visual effect of chromatic induction
Slika 2. Demonstracija psihofizikalnog vizualnog efekta kromatske indukcije

If you observe Figure 2 in the same way, the pairs of complementary colours (marked by 1 and 3) in comparison with the determined successive tones (with regard to the primary stimulus of the marked numbers 2 and 4) you will see the similar effect called *chromatic induction*. Violet-blue colour of the background induces the experience of yellow on its surface more than some other beige colour of the background, that is green-blue colour of the background induces the experience of the red colour more than violet colour of the background.

It is believed that the creation of psychophysical visual effect of chromatic induction can be at least partly explained by the localized chromatic adaptation.

Under the term adaptation, the ability of living organisms to change non-linearly and to adapt the sensibility of their sensory station in regard to the particular stimulus properties is understood, in order to specify them with enough information necessary for the processing on sensory or cognitive perception levels (creation of experience).

Chromatic adaptation is a visual effect based primarily on independent control of sensibility among the three groups of receptor stations (L, M and S) in our eye, which are called cones, whose mutual variations are evident primarily in different areas of spectral sensitivity [1].

2.2 The idea of gamut

Ideja gamuta

The recent different modern communication media and devices which are in everyday life used for the distribution of information, pose the determined limitations which refer to the information quantity that can be comprised and presented. Visual media are limited by the information quantity concerning the colour (and its characteristics) which can be presented. The same limitations are valid for the media and devices which are used in the process of graphic reproduction (scanners, digital cameras, computer monitors, different printers, digital and classic printing machines). This mentioned limited group (range) of information about colour for the determined visual medium/device is known in graphic technology as gamut. However there are different possibilities of interpretation of the basic ideas of the term gamut. That which connects the modern meaning of the term gamut in graphic technology with other areas of the use of the same word (mathematics, music, psychology) presents in fact the limitations referring to "*the most possible range*" of application.

The most used definition of gamut in cross-media reproduction system is given by CIE TC 9-03 commission. It says: *gamut is the total range (scope) of information about colour which is possible to reproduce in the given medium under the determined condition of viewing – this is the volume in colour space.*

The term media, from the previous definition refers to the medium for presentation or collection of information about colour (in additive models it is the device itself and its colour space: computer monitor, scanner, digital camera). In graphic technology the medium for the reproduction of original (images or scenes from the real world) is not the printing machine but the combination of the printing machine, colour and the printing substrate.

Mathematical description of gamut [8] on graphic reproduction (print) is given in the following relations:

If $\boldsymbol{\Omega}_{\mathrm{CIE}}$ is the range of the numerical values in the determined selected area of CIE independent colour space and if $\boldsymbol{\Omega}_{\mathrm{print}}$ is the numerical volume of the control values of printing medium colour (combination of devices, colour and substrate) then the set:

$$\boldsymbol{G} = \{\boldsymbol{t} \in \boldsymbol{\Omega}_{\mathrm{CIE}} \mid \exists\, \boldsymbol{c} \in \boldsymbol{\Omega}_{\mathrm{print}} \text{ for which is valued } \boldsymbol{F}_{\mathrm{device}}(\boldsymbol{c}) = \boldsymbol{t}\} \qquad [2.10.1]$$

determines the gamut of the mentioned device (medium). Similar is valued when speaking about the complementary set:

$$\boldsymbol{G}^{c} = \{\boldsymbol{t} \in \boldsymbol{\Omega}_{\mathrm{CIE}} \mid \nexists\, \boldsymbol{c} \in \boldsymbol{\Omega}_{\mathrm{print}} \text{ for which is valued } \boldsymbol{F}_{\mathrm{device}}(\boldsymbol{c}) = \boldsymbol{t}\} \qquad [2.10.2]$$

in which the colours outside the gamut $\boldsymbol{G}^{c}$ of the mentioned device (medium) are defined.

The mark $\boldsymbol{F}_{\mathrm{device}}$ represents the function which performs the transformation from the dependent colour space of the device/medium into the CIE independent colour space, $\boldsymbol{t}$ presents the information about colour in CIE independent colour space and $\boldsymbol{c}$ presents its transferred value in the dependent colour space of the device/medium.

Colours which are within $\boldsymbol{G}^{c}$ (that is the colours outside the gamut) and cannot be reproduced on the medium/device, must be put within the gamut, which the given device/medium can present. This process of setting the colours from one gamut into another gamut of different size (volume and characteristics) is called transfer and mapping of gamut. For colours which are within the gamut, the mapping is performed among the control values of the device/medium and CIE independent colour space.

2.3 Gamut mapping

Mapiranje gamuta

Analysing the production process of the print it is clear that during the colour reproduction, the description of the image original available at the beginning depends on the medium in which the image is present (or in which it will be present) and that the medium possesses different limitations connected to the manipulation and presentation of colour information. In the prepress, these media are different forms of the electronic devices which generate colours according to the suppositions of additive synthesis) scanners, digital cameras, computer monitors) while in the printing process the colours are generated on the basis of the subtractive synthesis, on the determined printing substrate (mostly on paper) via the given device (printer, digital or classic printing machine).

Because of the nature of the printing production chain (which is determined by different mentioned devices with the different physical characteristics) each further phase of the production process causes the determined information loss concerning colours which has the consequence that gamut of the original (scanner template or real scene) is, as a rule, always greater than the gamut of four colour (CMYK) print (Figure 3).

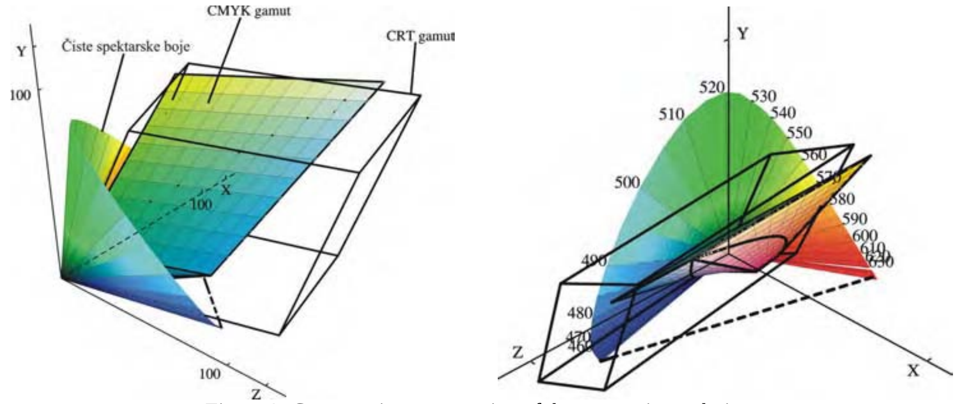


Figure 3. Comparative presentation of the gamut sizes relations
Slika 3. Usporedni prikaz odnosa veličina gamuta

This leads directly to the conclusion that it would not be possible to produce the particular colours of the original on the print. Methodology of reproduction (assigning) particular pieces of information concerning colour from one gamut into another (smaller or greater) is called gamut transforming or gamut mapping.

The aims of gamut mapping can be condensed in the tendency to ensure the correspondence of the total experience of colours between the two gamuts (the gamut of the original and the gamut of the reproduction) with the compensation inequality in size, shape and position of colours between the gamut of the original and its reproduction. Differences between two gamuts (original and the reproduction) for which there is the tendency to ensure the correspondence during mapping in total experience, can be: in size (circumference and volume) between the two gamut values, shape of the circumference or volume (shape of the boundaries of gamut) and the location of those gamut values within the uniform CIE colour space (most often L*a*b* or XYZ).

2.3 Transforming techniques and the gamut mapping

Tehnike transformacije i mapiranje gamuta

The transforming techniques and the gamut mapping determine the ways of decreasing differences in characteristics which exist between the original and reproduction gamut. Differences between the two gamuts, except in the final size expressed via volume of the colour space in which gamut is presented, can be in the form of circumference (gamut boundary form) and location, that is, intermediate position within the uniform CIE colour space. In regard to the prevailing methods of the mentioned differences, the transforming techniques and gamut mapping can be divided into three basic groups [2]: *cutting, compressing and expansion*.

Gamut cutting is the technique which is based exclusively on the change of those colours which are outside the circumference of the reproduction gamut, and which exist within the gamut of the original. This technique of the gamut mapping specifies the criteria according to which the colours being outside the gamut circumference and existing in the gamut of the original will be reproduced, but changed by means of the sizes which are on the boundaries of the reproduction gamut. The exactness of the described technique is variable and it depends primarily on the difference of the reproduction gamut size and the gamut of the original. The smaller the difference the greater the exactness, except in the case of the reproduction when the dominant colours are primarily within the boundaries of the mentioned gamut values.

Gamut compressing is the technique applied on all the colours of the original gamut so that the differences which are caused by non-matching of the sizes of the gamut original and the gamut reproductions are distributed in the whole area. All the colours which are in the original gamut try to represent themselves by the determined colours in the reproduction gamut. The compressing technique is applied as a rule in cases when there are greater differences between the gamut of the original and the gamut of the reproduction. It is applied because the technique of gamut cutting can result, in certain cases, in non acceptable loss of colour characteristics in the areas outside the reproduction gamut.

The gamut compressing technique, according to its characteristics can be *uniform* (equal for all the perceptual attributes) or *non-uniform* (when possessing different compressing parameters, depending on the type of the perceptual attributes).

The compressing techniques of the gamut mapping can be divided in three basic categories: *linear compression* is the simplest technique which proportionally (uniformly) compresses the colours of original gamut into the reproduction gamut; trying to keep the relation among colours which has often as the consequence the negative effect because of great aberration (shift) in tones, but the demands presented by [9] are satisfied, according to which the mutual relations among the colours in the image are more important than their precise values in realization of the total experience. *Non linear compression* is the non uniform technique of mapping which comprises the colours in the gamut of original and which is outside the reproduction gamut. Colours that can be realized on the reproduction gamut and on the original gamut stay unchanged. Third main techniques of the non-linear compression are logarithmic mapping, sigmoid technique and polynomial compression. *Combined compression* is the non uniform mapping technique which uses the combination of different compression methods and which can contain the cutting techniques.

The expansion technique of gamut is as a rule non linear extrapolation technique which is used very rarely. The aim of that technique is the increase of the gamut of the original in order to qualitatively exploit the area of the reproduction gamut. This technique is applied when the gamut of the original is expressively smaller than the gamut of reproduction in all areas of the CIE colour space (which is rare).

2.4 Orientation and dimensions of gamut transforming and gamut mapping

Orijentacija i dimenzije transformiranja i mapinga gamuta

Each of the previously mentioned techniques of gamut transforming and gamut mapping (cutting, compressing and expansion) is determined by the characteristics which are called **mapping orientation** (orientation in regard to the perceptual attributes) and **mapping dimension** (number of simultaneously used perceptual attributes in the process of gamut transforming and gamut mapping). Because of that it is necessary in the process of gamut transforming and gamut mapping to understand the fundamental connection of the dimension mapping, mapping direction and colour space in which mapping is performed, between the original and its reproduction.

As it was already mentioned the total gamut transforming and gamut mapping process (by standard methods) is performed within the uniform CIE L*a*b* colour space. The reason of the usage of CIE L*a*b* model lies in the fact that the mentioned colour model has excellent correlation with the perceptual attributes (hue, saturation and brightness) and the possibility of determining the three-dimensional image among the compared colours (ΔE^*). The majority of algorithms for gamut transforming and gamut mapping are made primarily for gamut transforming and gamut mapping with regard to the characteristics of the perceptual attributes. If the demands set to the transforming and mapping process are taken into consideration, it can be seen that they are determined primarily regarding the perceptual characteristics.

The number of the perceptual attributes with regard to the gamut transforming and gamut mapping process determines the term called dimensions of gamut transforming and gamut mapping. Gamut mapping performed with regard to only one perceptual characteristic of ink is called *one-dimensional* transforming and mapping. One-dimensional mapping (regarding the existing number of perceptual attributes) can be divided into transforming and mapping with regard to the brightness, transforming and mapping with regard to the chromaticity and transforming and mapping with regard to the hue. Mapping which is performed simultaneously with regard to two perceptual colour characteristics is called *two-dimensional* transforming and mapping. Two-dimensional transforming and mapping is performed simultaneously in the direction of brightness and chromaticity for constant values of the hue. The mapping is much rarer in the direction of hue where chromaticity or brightness is taken as another direction. Gamut transforming and gamut mapping which is simultaneously performed regarding all the three colour characteristics, brightness, hue and chromaticity is called *three-dimensional* transforming and mapping.

Except for *dimension* and *orientation,* the third parameter determines the transforming and gamut mapping technique. It is called *direction* of the gamut transforming and gamut mapping process Direction of the gamut transforming and gamut mapping process is performed via so called "lines" or "vectors" which are for colours of original gamut, the guidelines in relation to the reference values which can be realized on the reproduction. Directing of colour from the gamut of original is performed in relation to the axes of the perceptual attributes in relation to the concrete colour values of the reproduction gamut. The direction lines for performing the mapping process (which direct the mapping process) can be applied for each of the mentioned mapping techniques.

2.5 Standard ICC rendering methods

Standardne ICC metode renderiranja

Types, directions and dimensions of gamut mapping are determined by the applied rendering method in dependence on the desired reproduction intention. At the moment, there are four transforming methods and gamut mapping standardized by ICC (2001) [7]: *perceptual, saturation, relative colorimetric and absolute colorimetric method.*

Perceptual rendering is linear compressive technique with regard to the gamut mapping type, with the mapping direction oriented primarily towards brightness and then towards the chromaticity and hue. In perceptual rendering all the colours of the original gamut are transformed so that they become a part of the reproduction gamut, that is, they are compressed so that they can be completely or almost completely placed in gamut reproduction. By such transforming all the colours of the original gamut, even those which could identically be transformed into the reproduction gamut, are changed at the output. However the brightness axis (the range from the brightest hue to the darkest one) as well as the mutual relations among the hues are kept (their relative relations are kept). Perceptual rendering method fulfills the first from Mac Donald's gamut reproduction process aims – preserving the relation within the reproduction curve of the achromatic hues.

In perceptual rendering the exactness of the colorimetric colour characteristics is changed on behalf of the total conceptual experience which is based on keeping the relative relationship among colours. From the aspects of reproduction exactness the perceptual method satisfies the criteria of Hunt's equivalent or corresponding reproduction, that is, of screen reproduction according to the classification given by Moroney and Viggiano [10].

Saturation rendering, with regard to the gamut mapping type, is the combination of the non-linear compressive and cutting technique, although in certain areas which are directly next to gamut boundaries the expansion technique is used. With regard to the mapping direction, saturation rendering is oriented primarily towards chromaticity. In saturation rendering all the colours which are not a part of reproduction gamut are usually transformed into the nearest corresponding colours of the same saturation, while brightness and hue can be changed. Colours that are near the inner boundaries of the reproduction gamut shift towards the boundaries of gamut to increase the saturation.

Colorimetric exactness between the original and the reproduction in saturation rendering can in certain cases be kept, but it is not the priority. With regard to the exactness, saturation rendering method has characteristics asked in Hunt's preferred (wanted) reproduction, that is, reproduction for "graphic presentation" according to the classification given by Moroney and Viggiano.

Relative colorimetric rendering, with regard to the gamut mapping type, is the cutting technique of combination in particular areas with linear compressive techniques and with regard to the mapping direction it can be characterized as simultaneous three-dimensional technique with special algorithms oriented towards the colorimetric exactness (algorithm of so called minimal ΔE^* cut"). At relative colorimetric rendering, all the colours belonging to gamut of original and gamut of reproduction stay unchanged. Colours which are not a part of reproduction gamut are mapped into the nearest colours of equal brightness (relative in relation to the black and white dot), but with different saturation, which are on the boundary of reproduction gamut.

Mapping of numerous different colours of different brightness in one brightness value which is performed outside the reproduction gamut causes disturbances (loss of value) on the brightness axis and it is characteristic for relative colorimetric rendering that reproduction seems to be darker. In addition to the loss of hues and brightness in the area outside the reproduction gamut, another problem appears in absolute colorimetric rendering which is connected with the achromatic brightness axis and refers to different values of black and white dots on gamut of the original and gamut of the reproduction. In "cross-media" reproduction, which happens in the process of the printing production where there are additive (prepress) and subtractive media (printing) the problem appears connected to the black and white dot. Additive media, that is, their primers cannot influence the predefined values of the black dots (phosphorus without stimuli) and subtractive media cannot influence the predefined value of the white dot (colour of the printing substrate).

All the mentioned causes all relations among the hues and brightnesses in the image not to change in dependence on the substrate whiteness (they are relative) which results in incorrect hue presentation with regard to the achromatic axis. Because of that the term "relative colorimetric rendering" refers to the relative colorimetric exactness of all three-stimulus values in relation to the white reproduction dot of that medium. With regard to the intention of reproduction, the nearest colorimetric reproduction to the relative colorimetric colour rendering method is the one by Hunt, in relation to the relative reproduction classification given by Moroney and Viggiano.

The test form was created for the needs of investigations. It was composed of two parts, one part for instrumental analysis and one part for visual evaluation. The part for instrumental analysis Heidelberg PrintOpen 4-color Standard Test chart (the right part of the image 3) consists of 210 patches of different combinations of the subtractive synthesis colours, generated by vector graphics in the steps of 5 % screen value intended for Spectrophotometric analysis with the aim to calculate the gamut volume of the belonging reproductions. The part for visual evaluation consists of two image subparts made of vector generated elements (complex structure) by which the psycho-physical visual effect of the chromatic induction is manifested. The mentioned image presentations for visual evaluation are taken over from identical works created by Robertson [3] (the left part of the image 3) and Monnier & Shevell [3] (the middle part of the image 3) for their own investigations.

The test form created in previously described way is recorded in PDF format in CMYK colour space and printed on digital printing machine (the principle with liquid toner) with the resolution of 1200 x 1200 dpi with the application of the standard rendering methods: perceptual, saturation, relative colorimetric and absolute colorimetric method (Figure 4).

Glossy fine art paper coated on both sides of high whiteness was used as printing substrate (expressed in CIEL*a*b* values: $L^* = 94{,}4$, $a^* = 0{,}2$ and $b^* = 0{,}2$), grammage 175 g/m^2. The paper was conditioned before printing in the period of 48 hours in identical room, in determined standard ambient conditions (temperature 23 °C, relative humidity 55 %). The print run for each rendering method was 10 samples (because of the statistic exactness during the process of instrumental analysis). The instrumental analysis, i.e. the measuring of samples was performed with X-Rite DTP41 reflection spectrophotometer in the wavelength ranges from 390 to 710 nm, in steps of 10 nm and illumination geometry of 45°/0°. The exactness of the measuring device, that is the average aberration in the sense of reflectance is 0,5 %, per wavelength step. The reference standard for calibration was measured in MSCL laboratory on RIT with exactness of $\Delta E^*=0{,}25$, for the light source D50 and observation angle of 2°.

Visual evaluation was performed separately for each image part (image presentation created by Robertson in 1996 and image presentation created by Monnier & Shevell in 2004) through two separate research series in dependence on the set criteria by simultaneous binocular technique in which the primary (reference) and the test stimuli are one next to another in the whole field of sight at the same time.

In the first evaluation series the task of the examinees was to determine in which of the four presented samples, produced by the standard rendering methods they perceive the highest difference (mark 4) or the lowest one (mark 1) between the primary (reference) stimuli in relation to different background and environment. The research aim set in this way was to evaluate the influence of the applied rendering method and the belonging calculated gamut volumes on the magnitude manifestation of experience of psycho-physical visual effect of the chromatic induction.

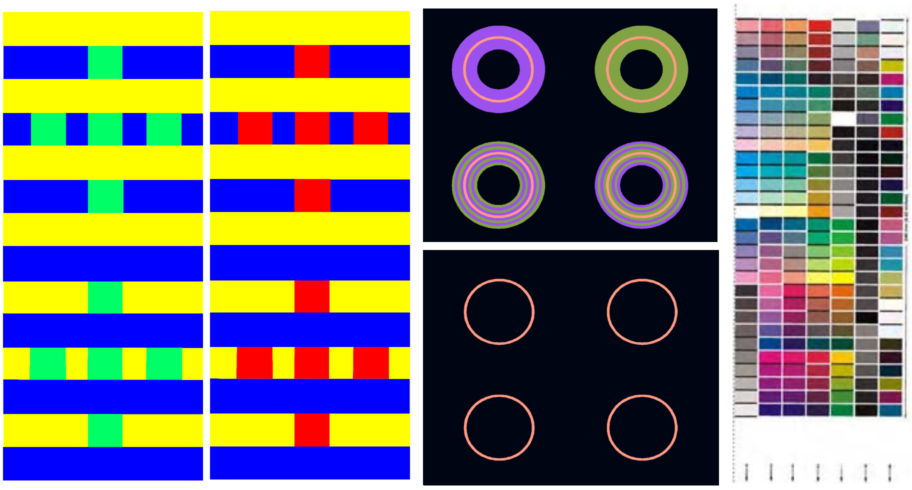


Figure 4. Presentation of the test form used in experiment
Slika4. Prikaz testnog oblika korištenog u pokusu

In the second series of visual researches the examinees were asked to evaluate which sample (print) was the most similar (mark 4) to the reference one on the screen monitor, that is with greatest aberration (mark 1) in the series of samples (produced by the standard rendering methods).

The aim of such set visual evaluations is to estimate the quality experience of prints (correspondence with the presented original), produced by four standard rendering methods in the cases of manifestation of the chromatic induction effects and to find the relationship among the mentioned research results and previously published quality research result of prints, produced by standard rendering methods for "real" image presentations Megavision and ISO 300; *Milković, Mrvac, Bolanča & Knešaurek* [3] and *Milković, Mrvac & Bolanča* [4] which do not cause the appearance of psycho-physical visual effects and which are in correlation with the results of the instrumental analysis, calculated gamut volume; and which in most cases support the hypothesis that the increase of the experience intensity of the graphic reproduction follows the increase of gamut size (realized by application of the determined ICC standard rendering method).

Visual evaluation according to the mentioned criteria, performed at the Chair for Printing at the Faculty of Graphic Arts, University in Zagreb, with the mixed population of 18 examinees (9 women and 9 men) with the average 21 years of age, in standard ambient conditions, in conformity with CIE TC 1-27 from 1994 (light source D54. Neutral light grey curtain in the background). The distance among the samples and the examinees ranged from 75 to 100 cm. The viewing direction and the evaluation time were not determined (they depended on the examinee).

The described visual evaluation of the image parts with regard to the applied psycho-physical research methods is combination of the techniques of *visual discrimination* which is based on detection of potential differences (aberrations) between the primary reference stimulus and test - researched stimuli and the technique *evaluation scale of the relationship size*, because during the experiment the examinees had to give the measurable (numerical) evaluation of mutual relationship of the primary (reference) and tested stimuli according to the demanded characteristics (in the concrete case applied in this work) the examinee had to give mark 4 to the sample which was most similar to the test stimulus and the mark 1 to the sample with the least similarity to the test stimuli in regard to the demanded characteristics).

4
Research results
Rezultati istraživanja

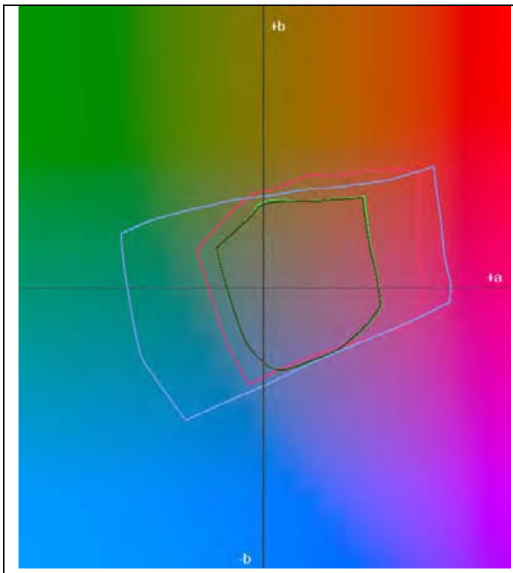
The results of the first series of visual evaluation of the printed samples for each examinee, in dependence on the estimation of the image template, (Robertson or Monnier & Shevell) and the applied rendering method and the results of the second series of visual evaluation of the printed samples ("cross-media" evaluation of the print quality by determining the correspondence with the reference original on the computer monitor) are presented comparably in Table 1, in which the letters c P, S, AK and RK represent the abbreviations of rendering methods: P=perceptual, S=saturation, RK=relative colorimetric, AK=absolute colorimetric. The derived results obtained on the basis of instrumental (Spectrophotometric) analysis *(by application of Monaco GamutWorks)* are presented in Figure 4 through 2D comparable presentations of gamut sizes and gamut volumes for each standard rendering method.

Table 1. Presentation of the visual evaluation results
Tablica 1. Prikaz rezultata vizualnog vrednovanja

	Image presentation "Robertson 1996"								**Image presentation "Monnier&Shevell 2004"**							
	I visual evaluation				**II visual evaluation**				**I visual evaluation**				**II visual evaluation**			
Ordinal number of examinee	**Rendering method**				**Rendering method**				**Rendering method**				**Rendering method**			
	S	**P**	**RK**	**AK**	**S**	**P**	**RK**	**AK**	**S**	**P**	**RK**	**AK**	**S**	**P**	**RK**	**AK**
1.	4	1	2	3	4	1	2	3	3	1	4	2	4	2	3	1
2.	4	1	3	2	3	1	4	2	4	1	2	3	3	1	2	4
3.	4	2	3	1	4	1	2	3	4	1	2	3	4	1	3	2
4.	3	1	4	2	4	1	2	3	3	1	4	3	3	2	4	1
5.	4	2	1	3	4	1	3	2	4	3	2	1	3	2	1	4
6.	3	1	4	2	2	1	4	3	4	1	3	2	3	1	4	3
7.	4	1	2	3	4	2	3	1	4	1	2	3	4	1	3	4
8.	4	1	2	3	4	1	3	2	4	1	3	2	3	1	2	3
9.	4	1	2	3	3	2	4	1	4	1	3	2	4	1	3	2
10.	3	1	4	3	3	2	1	4	3	1	4	2	4	2	3	1
11.	4	3	2	1	4	1	3	2	4	3	2	1	4	1	2	3
12.	2	1	3	4	2	1	4	3	3	2	4	1	4	1	2	3
13.	4	3	2	1	4	1	2	3	4	1	3	2	4	1	3	2
14.	4	1	2	3	4	2	1	3	4	1	3	2	3	1	2	4
15.	4	3	1	2	4	2	3	1	4	1	3	2	3	1	2	4
16.	3	1	4	2	3	1	4	2	4	1	2	3	3	2	4	1
17.	4	1	3	2	4	1	2	3	4	1	3	2	4	1	2	3
18.	4	1	2	3	3	1	2	4	4	3	2	1	4	1	3	2
Middle value	**3,7**	**1,4**	**2,6**	**2,4**	**3,5**	**1,3**	**2,7**	**2,5**	**3,8**	**1,4**	**2,8**	**2,1**	**3,6**	**1,3**	**2,7**	**2,6**

Table 2. Presentation of the added results of visual evaluation for real presentations Megavision and ISO 300 (AIC2004, Gamut Characteristics of Chromatic and Identical Desatured Achromatic Reproduction)
Tablica 2. Prikaz dodanih rezultata vizualnog vrednovanja za stvarni prikaz Megavision i ISO 300 (ACI2004, Gamut karakteristike kromatske i identične desaturacijske akromatske reprodukcije)

		Image record Megavision					**Image record ISO 300**			
		Rendering method					**Rendering method**			
Number of examinees	/	**S**	**P**	**RK**	**AK**	/	**S**	**P**	**RK**	**AK**
22		**2,0**	**2,0**	**3,0**	**3,1**		**2,1**	**1,9**	**3,1**	**3,0**



Rendering method	**Volume of gamuta** (CIE L*a*b* CCU)
Perceptual (presented by dark green colour)	396992
Saturation (presented by light green colour)	401812
Relative colorim. (presented by purple colour)	593611
Absolute colorim. (presented by blue colour)	682203

Figure 5. Results of instrumental analysis (2D presentation of gamut size relations for L=50 and gamut volume presentation in CIE L*a*b* CCU)*
Slika 5. Rezultati instrumentalne analize (2D prikaz odnosa dimenzija gamuta za L=50 i prikaz obujma gamuta u CIE L*a*b* CCU)*

5
Result discussion and conclusion
Diskusija rezultata i zaključak

It was found out by means of the first series of visual evaluation that the psycho-physical visual effects of the chromatic induction achieve the greatest experience magnitude (difference among the identical primers in dependence on the changed background) in both types of image samples (Robertson and Monnier& Shevell) by the application of perceptual rendering method. The results of visual evaluation collected for colorimetric rendering methods (relative and absolute) are mutually similar and they are between the saturation and perceptual methods in their value.

The results of instrumental analysis in relation to the results of visual evaluation show aberration from the ingrained point of view, according to which the increase of gamut size of prints is followed by the increase of the experience quality, that is the greatest evaluation value is realized by saturation rendering method (which has not the greatest gamut value at all). It is followed by colorimetric method with approximately equal evaluation values, while the perceptual method is the last one. Comparing the results of the visual evaluation of the quality experience (correspondence of prints with the presented original) in the case of manifestation of the chromatic effect induction (table 1) in which the highest evaluation values are given to saturation rendering method (followed by the colorimetric method with similar evaluation values, and at the end the perceptual method) with the results of visual investigations of quality experience for "real" image presentation Megavision and ISO 300 (table 2) which do not cause the psycho-physical appearance of visual effects (and which are in correlation with the results of instrumental analysis) the aberration from previous results was noticed, that is, the shift of the saturation method in front of the colorimetric methods.

The explanation of the obtained results connected to the saturation rendering method should be looked for partly in structural characteristics of the evaluated image record (shape, appearance frequency, size and mutual relation of primary and background stimuli), but mostly in colour characteristics of primary and background stimuli of the chosen test samples. Further on, the saturation method is considered to have primarily characteristics which are looked for "*preferred, (desired) reproduction*" (it is designed with the aim of chromaticity increase, while exactness is not the priority in colorimetric method). From the above mentioned, it can be concluded that the *intensity* of experience, which (according to the investigation results) directly influences the judgement of the experience quality (even in the cases when the evaluation of the colorimetric exactness in the cross-media evaluation technique is asked).

6
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