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Different Textile Materials as Light Shaping Attachments in Studio Photography and Their Influence on Colour Reproduction

Različni tekstilni materiali kot nastavki za oblikovanje svetlobe v studijski fotografiji in njihov vpliv na reprodukcijo barv

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Abstract
The research focuses on the quality of colour reproduction when using different light sources, often used to illuminate scenes in a photo studio, and different types of fabrics as lighting shapers. With the latter, the light can be converted into softer and more diffuse light, but the properties of the fabrics used affect the colour impression and thus the quality of the reproduced colours. This was evaluated by analysing the colour differences which were calculated from the colorimetric values of the colour patches of the X-Rite ColorChecker Passport test chart. Test chart was photographed in a controlled environment and illuminated with different combinations of light sources and tested fabrics. The results confirmed that not all combinations of variables are suitable for use if the goal of the photograph is to achieve high quality colour reproduction.
Keywords: photography, light, fabrics, colour reproduction, light shaping attachments

Izvleček
Raziskava se osredinja na kakovost barvne reprodukcije pri uporabi različnih svetlobnih virov, ki se pogosto uporabljajo za osvetljevanje scen v fotografskem studiu, in različnih vrst tkanin kot nastavkov za oblikovanje svetlobe. S temi lahko svetlobo preoblikujemo v mehkejšo in bolj razpršeno, vendar lastnosti uporabljenih tkanin vplivajo na barvni vtis in posledično na kakovost reproduciranih barv. Le-to smo vrednotili z analizo barvnih razlik, ki smo jih izračunali iz odčitanih kolorimetričnih vrednosti barvnih polj testne tablice X-Rite ColorChecker Passport. Ta je bila fotografirana v nadzorovanem okolju in izpostavljena različnim kombinacijam svetlobnih virov ter testiranih tkanin. Rezultati potrjujejo, da niso vse kombinacije spremenljivk primerne za uporabo, če je cilj fotografiranja kakovostna barvna reprodukcija.
Ključne besede: fotografija, svetloba, tkanine, reprodukcija barv, nastavki za oblikovanje svetlobe

1 Introduction

For photography, light is of crucial importance as it is needed for the ability to represent a subject/object. In a photo studio, the photographer himself controls the various properties of the light emitted by the lights on stage. These are usually the intensity and colour temperature, but we can also control other properties, such as softness and dispersion of the light beam, which is achieved by using light shaping attachments.

These attachments can be of various shapes, which affect the angle of the dispersed light. The consequence of the attachment's material is the quality of light, it being soft or hard [1]. Often used attachments are softboxes, which soften the original light by transmitting it through a white fabric.

Studio lighting continues to evolve with technological progress. Today, xenon studio flashes (stroboscopic lights) and continuous LED lights are increasingly used in studio photography. Unlike halogen lamps, they do not generate high temperatures between 400 °C and 1000 °C [2]. By reducing the operating temperatures of the lights, it is no longer necessary to use special fabrics with a high melting point to soften the light. Instead, fabrics of organic origin can be used, whose structure begins to change at temperatures around 150 °C [3]. We can also use polymer fabrics with lower melting points, since the working temperatures of available lights are now lower and will not melt the fabrics.

With a wider range of light shaping attachments, the amount of final light shapes also increases. By using light shaping attachments we transform also the colour of the original light emitted by the light source. Therefore, the light illuminating the scene cannot be described precisely.

This research focuses on the quality of colour rendering and correlation between five different lighting conditions and the use of five different types of fabrics as light shaping attachments. The findings of this research will benefit the understanding and describing light used in researches, since no prior research has been found addressing the problem of the effects of fabrics as light shaping objects on the quality of colour reproduction.

The study included three types of lights that are commonly used to illuminate the photographic scene, but are very different from each other, since they emit light of different intensity and colour temperature while producing different amounts of heat.

A photographic studio flash that illuminates the scene with a xenon lamp was used. Its light flashes are extremely short therefore this type of lighting does not involve high operating temperatures. The second type of light source that does not produce high temperatures are LED lights (light-emitting diodes), with which colour temperature and light intensity can be adjusted. The third type of lighting is the illumination with a tungsten halogen lamp (hereinafter referred to as halogen lamp). This type of light source generates higher temperatures during illumination, so when staging the scene, we must pay attention to the distance of the flammable materials from the light head [2].

Textile fibres rarely melt, as their change at high temperatures does not necessarily mean a change in physical state from solid to liquid. Exposure to a suitable temperature ensures a change in the crystalline structure, which is also referred to as melting in the literature [4]. Synthetic fibres such as polyamide and polyester therefore have a melting point at temperatures between 223 °C and 270 °C, depending on the properties of the fibre polymers. Natural fibres, such as cotton, linen and wool, do not melt but carbonize at a certain temperature, i.e. such changes begin to show at temperatures around 150 °C [4, 3].

In order to compare the influence of natural and synthetic fabrics on the quality of colour reproductions when used as light shaping attachments, five types of fabric were tested, made entirely from one of the five fibre types, cotton, linen, wool, polyamide or polyester. A series of natural and synthetic fibres has been chosen, since it has been studied that light reflects differently depending on the fibre structure [5]. A colour test chart has been illuminated using five different lighting conditions with alternating use of five fabrics as light shapers. Photographs of the scene were measured and the quality of colour reproduction assessed.

2 Experimental

For research purposes, a special cube that allows control over the tested light and limits the influence of its reflections has been created. With five different lights, the colour chart has been photographed and then the process repeated five more times, changing the fabric that served as the light shaping attachment. The combinations of variables and their labels are shown in Table 1.

Each combination of variables was photographed three times, making a total of 90 photos. By adjusting the whiteness and brightness of the photos, the variables that would affect the colour differences caused by using different light shaping attachments, in this case fabrics, were eliminated. After these adjustments, the RGB values of all the colour patches were measured. The average values measured from three photos of the same combination of variables were converted to CIELAB values, and then the colour differences between the values without and with fabric as the light shaping attachment were calculated.

Table 1: Combination of fabrics and lightning conditions used in the research and their labels

Fabric	Xenon	Halogen	LED 3230 K	LED 5000 K	LED 6260 K
Cotton (CO)	X/CO	H/CO	L3/CO	L5/CO	L6/CO
Linen (LI)	X/LI	H/LI	L3/LI	L5/LI	L6/LI
Wool (WO)	X/WO	H/WO	L3/WO	L5/WO	L6/WO
Polyamide (PA)	X/PA	H/PA	L3/PA	L5/PA	L6/PA
Polyester (PES)	X/PES	H/PES	L3/PES	L5/PES	L6/PES

2.1 Scene

The test cube

The photographs were taken in a photo studio where there is no influence of outside light. A 60 cm cube was made, lined on the inside with black felt (Figures 1 and 2), in order to prevent the reflectance of the light, which could affect the reproduction of the colour of the test chart.

There are two round holes 20 cm in diameter in the centres of the two opposite sides of the cube, which serve as openings for illuminating the test chart (Figure 1a). This ensures that the angle of the incident light on the test plate is always constant. Test chart was mounted on the holder in such a way that it was always evenly illuminated from the left and right at an angle of 45° (Figure 1b).

The tested light source was 30 cm from the sides of the cube and positioned so that the centres of the light source were aligned with the centres of the round cut-outs on opposites sides.

If a light shaping attachment was used, it was placed on the side of the outer part of the cube so that it completely and evenly covered the opening in the side (Figure 1c).

At the level of the illumination holes, there is an additional hole with a diameter of 10 cm which allows the camera to be mounted so that the lens reaches into the cube (Figure 1d). This limits the possibility of additional reflections in the lens and prevents the capture of light outside the test area.

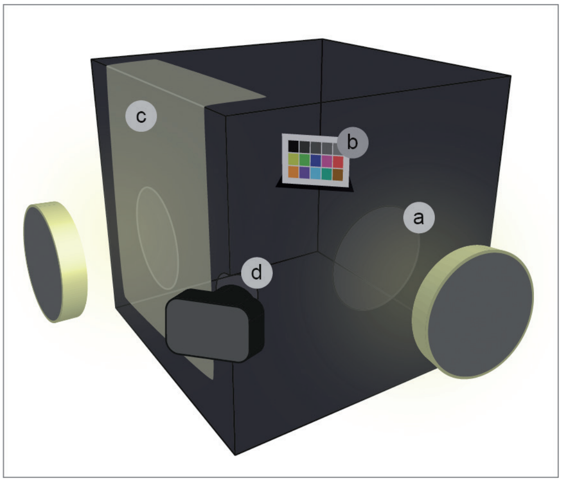

Figure 1: Test cube: a) illumination opening, b) test chart, c) fabric sample, d) camera opening

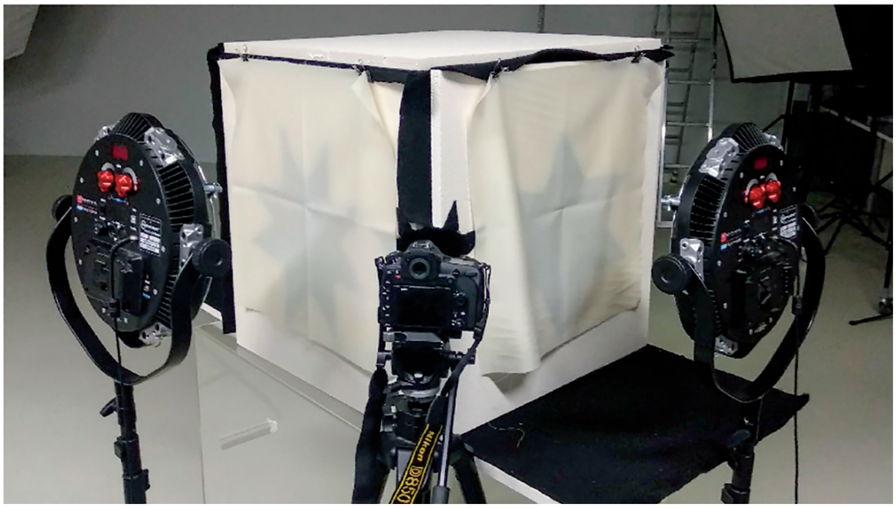

Figure 2: A photograph of the set

Colour test chart

To evaluate the quality of colour reproduction with different light shaping attachments, an X-Rite ColorChecker Passport Photo 2 test chart was photographed, which consists of twenty-four colour patches from the ColorChecker Classic colour plate [6, 7]. The RGB values of the colour patches on the test chart were measured with an X-Rite i1 Pro spectrophotometer and Argyll software, using the *spotread* command to perform the measurement. A two-degree observer and a standard D50 illumination were used. The CIELAB values obtained were converted to RGB values of the sRGB colour space, whose white point is D65. This is the same conversion method that is stated in the X-Rite manufacturer's specification for the values in the test chart used [8].

The measured RGB values of the colour patches deviate from the values given in the specification of the test plate [8], which has no influence on the final results of the study, since the values under different lighting conditions were compared, and not the colour differences between reproduction and original. The measured and reference RGB values are shown in Table 2.

Table 2: Comparison of the measured RGB values of colour fields and the values according to specification [6]

Patch number	Colour patch	According to specification			Measured		
		R	G	B	R	G	B
1	dark skin	115	82	68	119	84	68
2	light skin	194	150	130	201	145	129
3	blue sky	98	122	157	98	138	150
4	foliage	87	108	67	91	107	64
5	blue flower	133	128	177	130	127	172
6	bluish green	103	189	170	90	187	169
7	orange	214	126	44	222	125	44
8	purplish blue	80	91	166	71	90	168
9	moderate red	193	90	99	201	91	94
10	purple	94	60	108	96	60	102
11	yellow green	157	188	64	157	198	63
12	orange yellow	224	163	46	229	161	35
13	blue	56	61	150	43	65	149
14	green	70	148	73	66	150	73
15	red	175	54	60	183	52	56
16	yellow	231	199	31	241	203	7
17	magenta	187	86	149	198	85	148
18	cyan	8	133	161	52	133	166
19	white (.05*)	243	243	242	251	246	238
20	neutral 8 (.23*)	200	200	200	204	202	200
21	neutral 6.5 (.44*)	160	160	160	163	161	161
22	neutral 5 (.70*)	122	122	121	120	120	119
23	neutral 3.5 (1.05*)	85	85	85	83	81	81
24	black (1.50*)	52	52	52	51	50	50

Light sources

A photographic studio flash Elinchrom ELC500 PRO HD was used. The intensity of the light flash was regulated depending on the textile material tested, as these transmit different amounts of light and require uniformly illuminated images for each measurement. The light flashes at four intensities used, namely 8, 38, 53 and 75 J, lasted 1/2940, 1/4650, 1/5000 or 1/2740 s. Rotolight Anova PRO ECO FLOOD lights have been used as LED source, with which colour temperature

and light intensity can be adjusted. 100% intensity and three colour temperatures (3230 K, 5000 K and 6260 K) were used for testing, as the latter is due to the switching on and off of individual light emitting diodes that emit light in the cold or warm part of the visible part of the electromagnetic wave spectrum.
A Kaiser studio lamp H with maximum intensity and the Osram No. 64575 lamp with a power of 1000 W and an electrical voltage of 230 V were used to light the scene with halogen light.
An X-Rite i1 Pro spectrophotometer in light emission measurement mode and Argyll software were used to measure the light emission spectrum of applied lighting conditions. Each scene was measured three times in steps of 10 nm representing the brightness of the emitted light at wavelengths from 380 nm to 730 nm. The values of the measured emission spectra have been normalized for easier comparison and analysis.

Light shaping attachments (fabrics)
Images of fabrics were taken with a digital stereo microscope Leica S9i at 40-times magnification. Warp, weft and weave of the materials were determined. Thicknesses of materials was measured with micrometer Metrimpex 6-12-1/B and with measuring unit Mitutoyo ID-C125XB, while colour properties with a Spectraflash 600 Plus CT spectrophotometer, measuring reflected light under measuring conditions of ten-degree observer and a D65 white point. Measured CIE xyY values were used to calculate whiteness of the materials and were converted to CIELAB for further comparison.

2.2 Photographic equipment and settings

Nikon D850 DSLR camera and a Nikkor AF-S 50 mm 1:1.4G lens with a HOYA Pro1Digital 58 mm MC UV(0) filter were used to photograph the ColorChecker Passport Photo 2 test chart. The filter serves only as a protection for the lens and does not affect the quality of the colour reproduction.
Photographs were captured in the RAW output format (file type NEF) in order to obtain as much data as possible. The ISO value or sensor sensitivity setting was set at 100 for all the photographs in order to cause as little noise as possible. The white balance setting was changed according to exposure using camera presets and manual white balance settings as shown in Table 3 [9]. An aperture value of f/4.5 was used, due to the sharpness of the lens is at its best at this aperture and the degree of colour distortion (chromatic aberration) is among the lowest [10]. The shutter speed was adjusted according to other settings so that the photo exposition was ideal. Shutter speed was monitored using a camera light meter and histogram analysis of each photo. The exposure time required was influenced by the type of lighting, as not all lights provide the same intensity of light emitted, and by the tested fabric, as each allows a different amount of light to pass through, thus affecting the brightness of the scene.

2.3 Method of analysis

All photos were imported into Adobe Lightroom Classic CC 2019 where we used the Crop tool to crop the edges of the photographed test charts (Figure 3). This reduced the size of the photos per area, resulting in a smaller file size. However, the data important for analysis is retained. The dimensions of the final photos are approximately 1500 px × 1000 px (pixels), with minor size variations, and a resolution of 300 ppi (pixels per inch).
For all cropped photos the whiteness was set to colour field no. 22, in order to colour match the photographs. The white balance adjustment was made in the largest possible range of 15 px × 15 px.
The NEF photo format is no longer suitable for further processing of photos and the information they contain. Therefore, they were exported to a 16-bit TIFF format, which is the least lossy export format available. The exported photos were opened in the ImageJ program. Since the photos are 16-bit TIFF, the program displays them as grayscale values of each colour channel (red, green and blue). Therefore, they were converted to a 32-bit RGB colour image using the *Image - Type - RGB Colour command* [11, 12].
It was also necessary to unify the brightness of the photos, as it was not possible to ensure exactly the same light intensities due to the lighting conditions.

Table 3: Setting the white balance for all used light sources

	Xenon	Halogen	LED 3230 K	LED 5000 K	LED 6260 K
White balance setting	preset Flash (5400 K)	preset Incandescent (3000 K)	Choose colour temp. – 3230 K	Choose colour temp. – 5000 K	Choose colour temp. – 6260 K

Figure 3: Photo of the test chart after cropping with marked colour patches regarding to Table 2

For the control area the colour field no. 22 was chosen, which has RGB values of 120/120/119. With the *RGB Measure plug-in* [13] average RGB values in the area of 100 px × 100 px in the colour field were read. Since the colour adjustment was already provided for when the white balance was set, the ratios of the read RGB values match, but in some photos, it was necessary to lighten or darken by adjusting the brightness. The measurement of the RGB value was repeated and the procedure was repeated until a sufficiently good adjustment was made to reach the reference RGB values of 120/120/119. The corresponding brightness was checked on all 90 photos and adjusted it if necessary. All 24 colour patches in 90 photos were then converted to RGB values, measuring areas of 100 px × 100 px. The same combination of variables was photographed three times, so in the next step we calculated the average RGB values of the individual colour fields in three photographs of the same combination of variables. CIELAB values were needed to calculate the colour differences and thus determine the impact of using fabrics as light shaping attachments.

The conversion was first done between RGB and CIEXYZ then between CIEXYZ and CIELAB [14, 15]. The average R, G and B values of the colour patches were normalized and the inverse sRGB compression function (Equation 1) was used to obtain the linear values of *r*, *g* and *b*. These were multiplied by the matrix *M* (Equation 2) with respect to equation (Equation 3). The matrix *M* considers the sRGB colour space and the white point D65 [16]. The result are normalized values of *X*, *Y* and *Z* which are divided by the corresponding X_r, Y_r and Z_r values of white point D65 (Equation 4) [17] according to equations (Equation 5), (Equation 6) and (Equation 7) to obtain the values of x_r, y_r and z_r. From this f_x, f_y and f_z with respect to the values of Equations 8, 9 and Equations 10, 11 and 12 were calculated. The spectral distribution functions f_x, f_y and f_z are used to calculate the values of L^*, a^* and b^* with respect to Equations 13, 14 and 15. To calculate the colour differences, the equation CIE 1976 (Equation 16) was chosen [18]. According to Equation 17 [19], the colour purity *C* was calculated for each colour field under different test conditions and then the differences between the illumination without and with fabrics as light shaping attachments were determined.

$$v = \{V/2{,}92 \; ((V+0{,}055)/1{,}055)^{2{,}4} \; \frac{if\ V \leq 0{,}04045}{if\ V > 0{,}04045} \tag{1}$$

$$[M] = [0{,}4124564\ 0{,}3575761\ 0{,}1804375\ 0{,}2126729\ 0{,}7151522\ 0{,}0721750\ 0{,}0193339\ 0{,}1191920\ 0{,}9503041] \tag{2}$$

$$[X\ Y\ Z\ ] = [M][r\ g\ b\ ] \tag{3}$$

$$[X_r\ Y_r\ Z_r\ ] = [0{,}95047\ 1{,}00000\ 1{,}08883\ ] \quad (4)$$

$$x_r = \frac{X}{X_r} \quad (5)$$

$$y_r = \frac{Y}{Y_r} \quad (6)$$

$$z_r = \frac{Z}{Z_r} \quad (7)$$

$$\kappa = 903{,}3 \quad (8)$$

$$\epsilon = 0{,}008856 \quad (9)$$

$$f_x = \{\sqrt[3]{x_r}\ \frac{\kappa x_r + 16}{116}\ \frac{if\ x_r > \epsilon}{if\ x_r \le \epsilon} \quad (10)$$

$$f_y = \{\sqrt[3]{y_r}\ \frac{\kappa y_r + 16}{116}\ \frac{if\ y_r > \epsilon}{if\ y_r \le \epsilon} \quad (11)$$

$$f_z = \{\sqrt[3]{z_r}\ \frac{\kappa z_r + 16}{116}\ \frac{if\ z_r > \epsilon}{if\ z_r \le \epsilon} \quad (12)$$

$$L = 116 f_y - 16 \quad (13)$$

$$a = 500(f_x - f_y) \quad (14)$$

$$b = 200(f_y - f_z) \quad (15)$$

$$\Delta E = \sqrt{(L_1 - L_2)^2 + (a_1 - a_2)^2 + (b_1 - b_2)^2} \quad (16)$$

where (L_1, a_1, b_1) are first and (L_2, a_2, b_2) second colour

$$C = \sqrt{a^2 + b^2} \quad (17)$$

The colour differences for each colour field of the test chart were calculated, describing the influence of the use of different fabrics and lighting types on the colour reproduction. The colour difference value is described by the perception of a standard observer, where:

$0 < \Delta E^*_{ab} < 1$ – the observer does not notice the difference between the colours,

$1 < \Delta E^*_{ab} < 2$ – only an experienced observer notices the difference between the two colours,

$2 < \Delta E^*_{ab} < 3{,}5$ – even an inexperienced observer notices the difference between the colours,

$3{,}5 < \Delta E^*_{ab} < 5$ – an obvious difference between the colours is observed,

$5 < \Delta E^*_{ab}$ – the observer perceives the colour as two different [20].

To make the results easier to interpret, the mean values of the colour differences for each test combination from 24 colour differences of individual colour patches were calculated.

3 Results and discussion

3.1 Light sources properties

Figure 4 shows the emission spectrum of the light flashes at the four intensities used, namely 8 J, 38 J, 53 J and 75 J, which lasted 1/2940 s, 1/4650 s, 1/5000 s or 1/2740 s. The spectral distributions are similar. The variability of the curve of the emission spectrum increases with the intensity of the flash, which is due to the greater amount of light and thus the possibility of a more accurate reading of the measuring

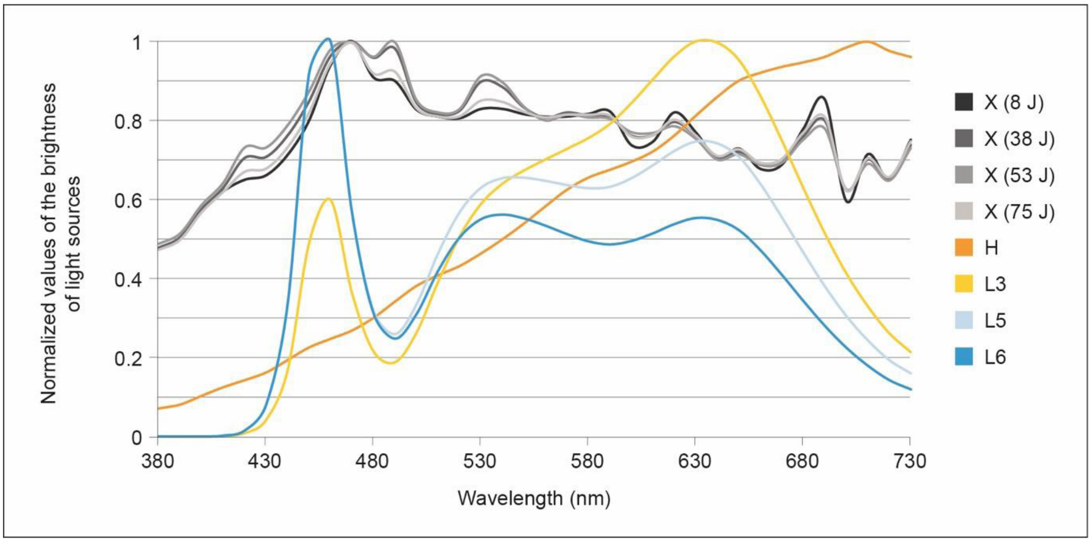

Figure 4: Normalized emission spectra of all used light sources

device. The normalized emission spectra of the emitted lights from halogen source (H) and three LED sources with colour temperatures 3230 K, 5000 K and 6260 K (L3, L5 and L6, respectively) are shown in Figure 4 as well.

Spectral distributions differ depending on the used light source (Figure 4). A light source X with a xenon bulb emits the most uniform spectrum, because its maximum is indistinct in the blue part of the spectrum but shows less emitted light in the purple part. A light source H with a tungsten halogen bulb emits the greatest amount of light in the orange-red part of the spectrum, while LED light sources vary according to colour temperature. L3 shows a smaller fall in the blue part of the spectrum, while the curve rises sharply in the yellow-orange spectrum. This indicates the warm light from the light source. Standard light at 5000 K represents the light source L5, which has a maximum in the blue part of the spectrum and corresponds to the maximum of the light source L6. They differ from each other by the emitted light between the wavelengths 530 nm and 780 nm, with white light having higher values.

3.2 Fabrics properties

The values of fabrics' variables are shown in Table 4. In Figure 5 the images of fabrics are represented, showing the differences in fabric density and weave. The calculated colour properties in CIELAB are pictured in Figure 6, while in Figure 7 the differences can be observed visually.

The differences in the measured colorimetric values are mainly due to the yarns used, which are derived from the raw material composition. Twisted yarns are used in natural fiber fabrics, i.e. CO, LI and WO, while synthetic fabrics, i.e. PA and PES, are made from multifilament yarn. The uniformity of the yarn structure has a significant influence on the perception of light passing through it. In the case of wool and polyester fabrics, where the yarns used are the most voluminous (Figure 5), the pores are the smallest and consequently the differences in light colour are the greatest (Figure 6). The passage of photons through the pores has no effect on their transformation, whereas the passage of photons through the yarn significantly transforms them, resulting in a greater change in colour (Figure 6). The degree of whiteness varies significantly, where wool has the lowest level of whiteness and poliester the highest, the latter being a consequence of high amount of optical brightening agents.

3.3 Colour differences

Colour differences ΔE^*_{ab} of individual colour patches are presented in Figure 8. A red line indicates the value 2, which illustrates the boundary between the colour differences that can be recognized by any observer. Figure 9 shows the average values of all measurements according to the tested light sources and fabrics.

The average colour differences (Figure 8) show that the greatest differences occur with the halogen

Table 4: Specification of tested fabrics. Temperature of change is taken after [3, 4].

Fabric	Label	Weave density (cm^{-1})		Weave	Thickness (mm)	CIE x	CIE y	CIE Y	W	Temperature of change (°C)
		Warp	Weft							
Cotton	CO	40	40	plain	0.228	0.318	0.336	91.57	79.71	150
Linen	LI	20	20	plain	0.435	0.327	0.345	80.80	46.44	150
Wool	WO	30	20	plain	0.359	0.338	0.358	69.84	(4.58)	150
Polyamide	PA	90	40	plain	0.140	0.317	0.334	90.29	82.63	223–265
Polyester	PES	20	20	plain	0.445	0.294	0.306	86.95	145.29	270

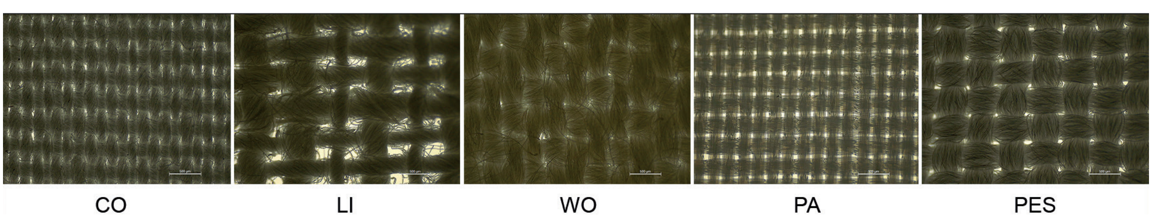

Figure 5: Images of tested fabrics under 40× magnification

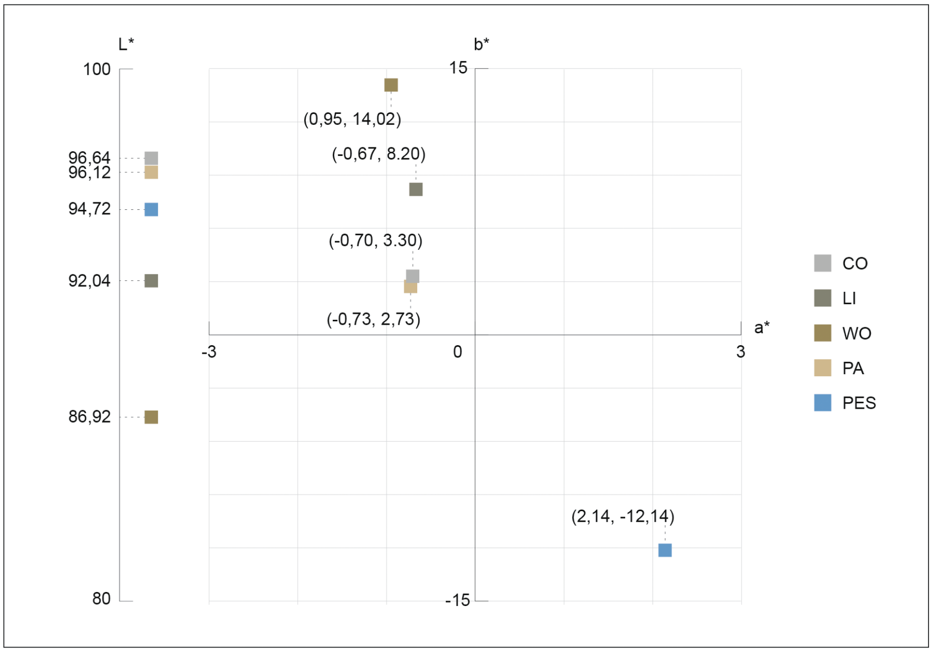

Figure 6: CIELAB values of tested fabrics

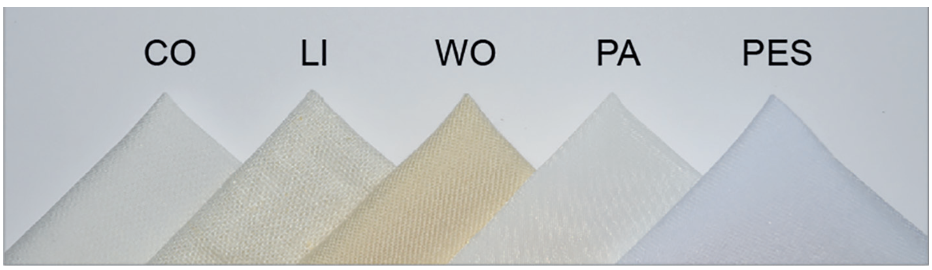

Figure 7: Colour comparison of tested fabrics

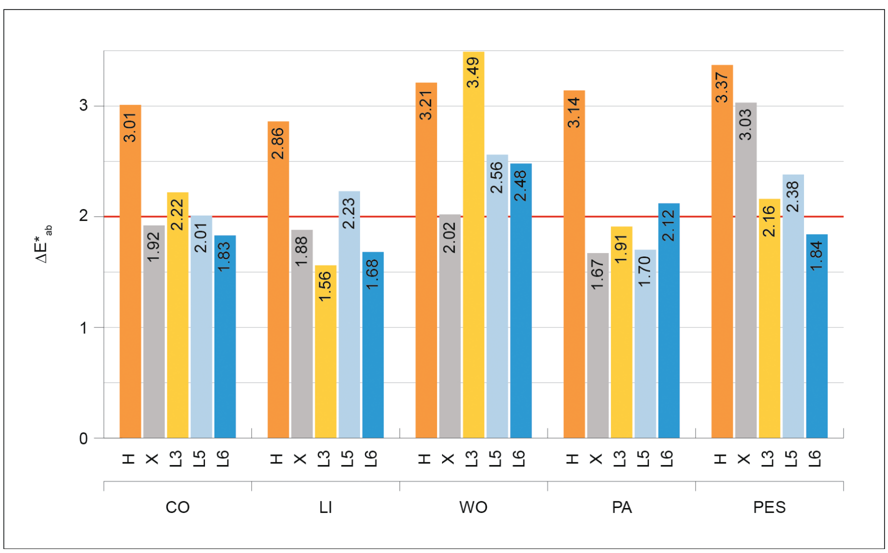

Figure 8: Average values of the colour differences ΔE^{*}_{ab} of twenty-four colour patches for each tested light source and fabric combination

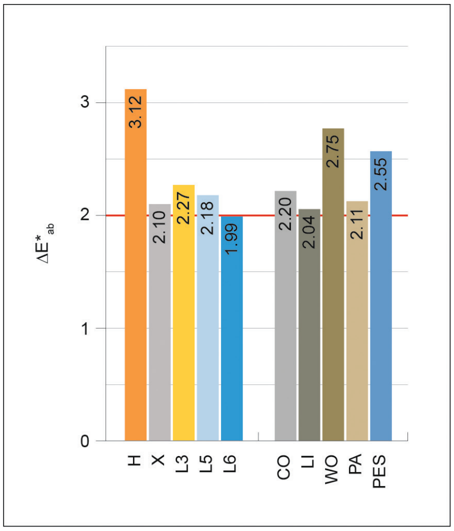

Figure 9: Average values of colour differences for each light source and fabric

light source (marked H) and independently of the fabric used. The values are between 2.86 and 3.37, indicating a recognizable difference between the colours. The other four tested light sources give better average results, as the average colour differences according to Figure 8 are between 1.99 and 2.27. Xenon light (marked with an X) causes the smallest colour differences when using different fabrics, however, we observe a large difference in the illumination through polyester (PES). The LED light sources L3, L5 and L6 give similar results, but individual differences are noticeable, i.e. in the combinations L5/LI and L3/WO. The smallest colour differences were measured when using linen (LI) and polyamide (PA), followed by cotton (CO). Wool (WO) is the least suitable, due to the large colour difference reflected by all tested light sources. The same applies to PES, which however shows completely different deviation tendencies than WO under different light conditions.

When comparing the colour differences in xenon flash illumination, it was noticed that PES causes a large colour difference, which is also perceived by an inexperienced observer. The use of wool also results in a colour difference greater than 2, but an excess of 0.02 is neglected. From Figure 10 we can see that

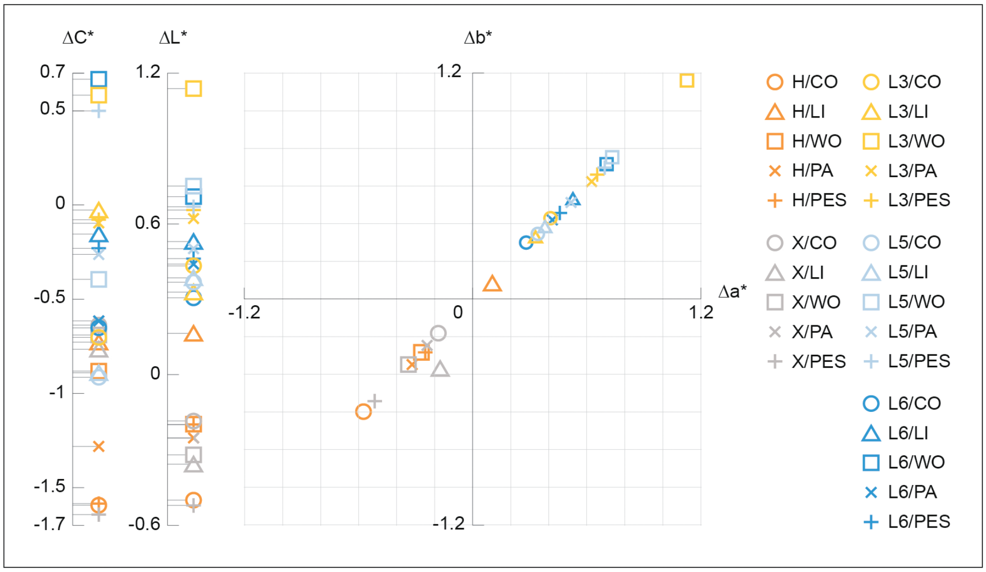

Figure 10: Display of colour deviations ΔC^*, ΔL^*, Δa^* and Δb^*, which occur when using different types of lighting and fabrics

the PES fabric in combination with xenon light X is different from the other four combinations of this light with other fabrics. It shows a greater colour shift towards green and blue and a lower brightness. The difference in colour hue can be related to the whiteness of the fabric (Figures 6 and 7), as the only fabric tested did not show any yellowing. The PES fabric is also sparsely weaved, which means that a lot of transmitted light is undeformed, so that the colour reproduction is affected by the cold light from light source X. ΔC^* also shows the deviation of X/PES from other combinations with light X, as it gives the lowest value, which means that the colours reproduced are less pure. We conclude that the fabrics CO, LI, WO and PA in the tested composition and weave density are suitable for use as light shaping attachments when using xenon light.

The same trend as X/PES is shown by H/CO, i.e. a combination of halogen light with cotton fabric. The similarity of the mean values of the colour differences from Figure 8 is then also observed in Figure 10, where the same colour deviation is shown along the axes L^*, a^*, b^* and C^*. CO is a slightly yellowed fabric with a higher weave density, which means that it reflects most of the yellow spectrum of electromagnetic waves. The rest is absorbed by the fabric, and some of it travels on, as the textile fibres are not completely opaque and allow light to pass through. The tested cotton fabric has a high weave density, which means that it transmits less unshaped warm light. This may justify the colour shift towards a green-blue hue, despite the use of a warm light source. For comparison, we can take H/LI, whose weaving density is half that of CO, and the yellowing is even higher. As more unformed light is transmitted, the colour hue differences shift towards yellow-red. Even though some shifts in hue are similar for both X and H lighting, the colour differences are large because the ΔE^*_{ab} equation takes all three parameters L^*, a^* and b^* into account. From the results, it can be therefore concluded that the tested fabrics are not suitable for use in combination with halogen light sources, as the influence on the quality of colour reproduction is too great.

The test combinations in which LED light sources were used show similar changes in colour hue and brightness, the only significant deviation occurs in the L3/WO combinations, which represent warm light at 3230 K and the use of woollen fabric. The sparse weave density of the wool fabric causes a higher light transmission and, in combination with its yellowing, the degree of which is the highest of all the fabrics tested, causes the greatest shift in colour hue towards yellow-red. Figure 10 shows that the same trend of colour shift when using WO also occurs with the other two LED light sources (L5 and L6). Despite the colour shift and therefore poor colour reproduction, WO in combination with warm and cold LED light (L3 and L6) produces cleaner colours. A third such example is the L5/PES combination, which is in complete agreement with the findings made in this paragraph for wool and LED light combinations. Other LED lighting combinations and the use of the other four fabrics show similar results without particular variations with respect to the values L^*, a^*, b^* and C^*. It can be concluded that the fabrics CO, LI, PA and PES are suitable for shaping the light from LED light sources, apart from the combination L5/PES, which represents LED light at 5000 K and polyester fabrics.

4 Conclusion

Colour differences are influenced by the interaction of light and fabric. Since the latter differ in colour and weave density, they transmit different amounts of light and absorb different parts of the visible spectrum of electromagnetic waves. Research has shown that the quality of colour reproduction is influenced by light sources and different properties of fabrics used as light shaping attachments, as the final colour impressions depend on their whiteness and weave density. It is assumed that the opacity of textile fibres also plays an important role, which opens new possibilities for further research.

Considering the variables of the light source and the density and whiteness of the tested fabrics, it can be concluded that not all combinations are suitable for use if we want to achieve good colour reproductions. If xenon light is used as the light source on the photographic scene, they are suitable for the use of CO, LI, WO and PA with tested properties, whereas there are large colour differences when PES is used. Not only are most fabrics not suitable for use near halogen light sources due to the high operating temperatures of the lamps, it also turns out that the colour differences are the largest of all tested combinations. This leads to the conclusion that halogen lamp types, regardless of the fabric used, are not suitable for high-quality colour rendering. LED light sources allow the widest range of fabrics, as the colour rendering is satisfactory when using all but WO. An exception is the combination of a light LED source with a colour temperature of 5000 K and the use of PES, so the use of such combination is not recommended.

The research led to the conclusion that the most significant impact on the quality of colour reproduction is a consequence of the whiteness of the fabric used as light shaping attachment on the light source. The type of the fabric has not shown itself as significant, while its weave density plays an important role. The denser the fabric, less opening are in it and less light is transmitted undeformed, therefore the change is lower. While fabrics with higher weave densities transform the light in a higher manor, resulting in more obvious changes, in our case wool and polyester.

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