Permanence of Inkjet Prints in Relation to Typographic and Colorimetric Characteristics

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The accessibility and usage of various mobile devices is increasing; nevertheless, paper still plays a significant role in our daily lives. Despite well-known recommendations for preserving different substrates used in the graphic arts production (e.g. paper), there have been until now no available standards about the preservation of different typeface styles and type sizes which would offer an inkjet print better quality and better fastness, ensuring legible information. The purpose of this study was to examine the influence of light on the changes in typographic and colorimetric properties of inkjet prints in order to establish an appropriate typographic style for the design of printed information to ensure best permanence.

The prints were made with two inkjet printers on four office papers in four colours (red, green, blue, black). Four widely used typefaces (one old-style, one transitional and two sans-serif) in three sizes (10, 12 and 16 pt) were tested. The printed samples were exposed to light for 72 hours in Xenotest Alpha. The resistance of printed information to light was evaluated according to the ISO 12040 standard. The changes in colour were determined spectrophotometrically, while the differences in typographic tonal density of typefaces were evaluated with image analysis using the ImageJ software.

After the exposure to light, the most evident colour differences were detected on blue prints. The measurements showed that black prints are much more stable than colour prints. The lowest typographic tonal density on the prints was observed at the old-style typeface and transitional typeface. The results showed that sans-serif typefaces have higher typographic tonal density. The smallest differences in typographic tonal density after the exposure to light were observed at both sans-serif typefaces (i.e. Arial, Verdana), suggesting that such typefaces are more appropriate for permanent documents.

1. Introduction

The inkjet technology has recently become important and widely used in many different areas, not only for home application but also for printing documents and various display works. For the latter, fastness of prints can present a problem. Under the influence of external factors, e.g. light, heat and humidity, the appearance of an inkjet print can change significantly. Fading is especially evident on the prints made with dye-based inks. [1]

In typography design, it is useful to be familiar with typographic tonal density (or typographic tonality) of different typographic elements, which refers to the relative blackness or shades of grey of type on a page. Typographic tonal density (TTD) can be expressed as the relative amount of ink per square centimetre, pica or inch. [2] The changes in various type features can create variations in typographic tonal density. Such features include typeface (style of letterform – stroke width, set width, counter size, x-height (cf. Figure 1)), caps, italic, bold, compressed and extended (and all variations in weight and width), type size, letter and word spacing, leading etc. [3–5] Typefaces with large counters trap a larger amount of white space in the enclosed spaces of letters, e.g. o, a, g and p. The cumulative effect decreases typographic tonal density. A thicker stroke width results in more ink per area. [5–7] Most sans-serif typefaces therefore need more ink per area. The reason is in their design, as the contrast between the strokes of characters is limited and the sans-serif typefaces have little or no difference between thick and thin strokes. [6, 7]

The purpose of this study was to examine the influence of light on the changes in the typographic and colorimetric properties of inkjet prints to establish which typeface style ensures best information permanence.

2. Experimental part

2.1 Paper properties

The prints included in the study were made with two inkjet printers on four different widely used office papers. One of them, paper 3 (S3), has a recycled paper declaration. Prior to printing, their basic, surface and optical properties were measured. Paper grammage was measured according to the ISO 536 standard [8], while thickness, and specific volume or density, respectively, of the paper were measured according to the ISO 534 standard [9]. The measurement of paper roughness was conducted with the Bendtsen method in accordance with the ISO 8791/2 [10] standard. The porosity of paper was tested according to the Bendtsen method with regard to the ISO 5636/3 [11] standard. The water absorption of paper was measured with the Cobb method in accordance with the ISO 535 [12] standard. Gloss measurement was conducted on the Lehmann equipment in accordance with the TAPPI 480 standard [13] and paper brightness in accordance with the ISO 2470 standard [14]. The opacity of paper was measured with regard to the ISO 2471 standard [15]. The measured properties of the paper felt side are presented in Table 1.

2.2 Typographic and colorimetric properties of prints

Colour prints (S1–S4) were made with two inkjet printers: HP DeskJet 5740 (P1) and Epson Stylus DX 8450 (P2). The printer Epson Stylus DX 8450 (P2) uses inks comprised of pigments. Four different, widely used typefaces were tested, namely two sans-serif (Arial and Verdana) [6, 16], one old-style (Palatino) [6, 16] and one transitional typeface (Times) [6, 16], each in three different sizes (i.e. 10, 12 and 16 pt). On each of the four papers, three field intensities were printed, i.e. of 80% (K80), 60% (K60) and 40% (K40). Colour prints with three intensities were printed in red (R80, R60, R40), green (G80, G60, G40) and blue (B80, B60, B40).

2.3 Light fastness of prints

The resistance to light of printed samples was evaluated according to the ISO 12040 standard [17], using Xenotest Alpha (Atlas), with a xenon arc lamp. The colour temperature was between 5500 and 6500 K at a constant temperature of 35 °C and constant relative

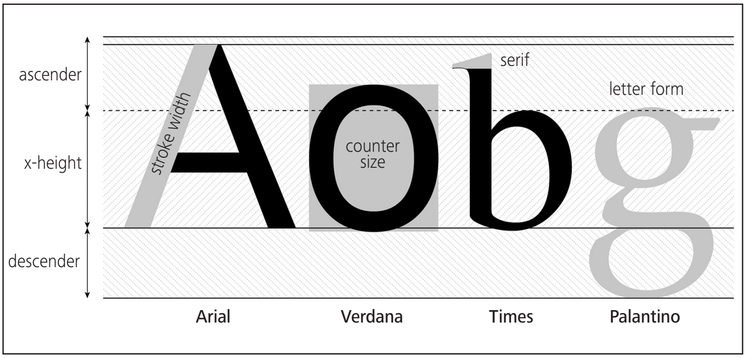

Figure 1: Some typographic characteristics important for text legibility, i.e. ascender, x-height, descender, contrast or stroke width, counter size, shape and size of serifs, and letter form

Properties	S1	S2	S3	S4
Grammage (g/m²)	79.13	78.71	79.75	78.88
Thickness (mm)	0.098	0.100	0.100	0.103
Specific volume (cm³/g)	1.23	1.26	1.26	1.30
Roughness (ml/min)	160	71	175	205
Porosity (ml/min)	959	992	646	875
Water absorption (g/m²)	32.30	35.00	30.90	37.60
Gloss (%)	3.80	5.60	4.30	3.50
ISO Brightness (%)	98.30	97.93	78.15	102.02
Opacity (%)	94.85	96.07	94.70	93.40

Table 1: Properties of tested papers (S1–S4)

humidity of 35%. The samples were exposed to xenon light for 72 hours.

The CIE L*a*b* parameters were measured with the spectrophotometer EFI/ES – 1000 (Gretag Macbeth) in accordance with the ISO 13655 standard [18]. The colour difference (ΔE) between the non-exposed and exposed samples was calculated according to the CIELAB equation for colour differences [19]:

$$\Delta E_{ab}^{*} = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}} \quad (1)$$

The differences in typographic tonal density of the non-exposed and exposed typefaces were measured numerically by means of image analysis (ImageJ software) [20]. All the measured samples were of the same size, i.e. 2100 × 360 pixels.

3. Results and discussion

3.1 Influence of light on typographic properties

The typographic tonal density of each typeface, each in different size, was measured on the non-exposed and exposed samples. The samples with the highest and the lowest typographic density, and their differences in typographic density after the exposure are presented in Figures 2–5.

The results show (cf. Figures 3, 5) that sans-serif typefaces have higher typographic tonal density, which was expected due to smaller differences in letter stroke width. The lowest typographic tonal density was observed at the transitional typeface Times and at the old-style typeface Palatino. The difference between thick and thin strokes at Times letters is substantial. Palatino letters have big counter size, the difference between thick and thin strokes is not very significant, and thick strokes are not very wide. After the exposure to light, the most noticeable difference in typographic tonal density occurred at the old-style typeface Palatino and at the transitional typeface Times. Evidently, the old-style typefaces, where thick strokes are not very wide and serifs are smaller, and the transitional typefaces, where the difference between thick and thin strokes is significant, are not resistant enough to the influence of light. The destructive influence of light is namely more evident on thin strokes. The smallest difference in typographic tonal density of the non-exposed and exposed samples was seen mostly at the sans-serif typefaces Verdana and Arial. The obtained results show the biggest differences at the typefaces used in the size 16 pt (cf. Figures 3, 5). The typographic tonal density at smaller typeface sizes is usually higher due to the smaller counter size of letters and leading (i.e. space between lines).

The smallest changes in typographic tonal density were, as expected, obtained on the samples printed with P2, which uses pigment-based inks (cf. Figures 2, 4). Moreover, the samples printed with this printer had in general the highest typographic tonal density. The largest differences in typographic tonal density were observed on the red and green samples printed with P1 (cf. Figure 6). Among the printed samples, most noticeable differences appeared above all on S4 and the least noticeable on S3, where on average, the highest typographic tonal density before the illumination was measured. This paper exhibits the smallest porosity which can influence the distribution of ink during the printing process and affect the amount of ink bound closer to the surface.

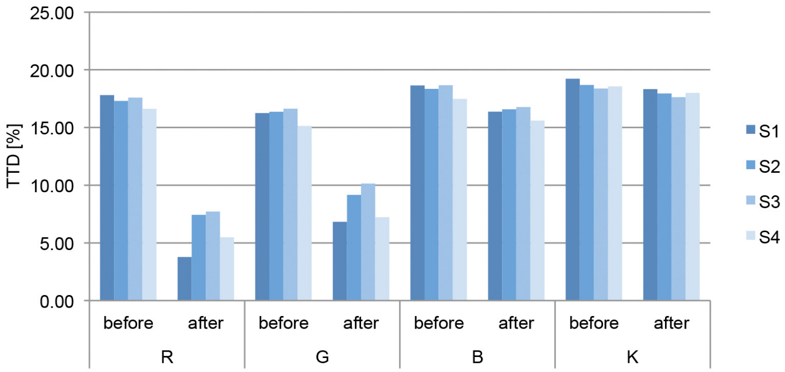

Figure 2: Average value of typographic tonal density (TTD) for R, G, B, K prints on different papers (S1–S4) printed with Printer 1, before and after exposure

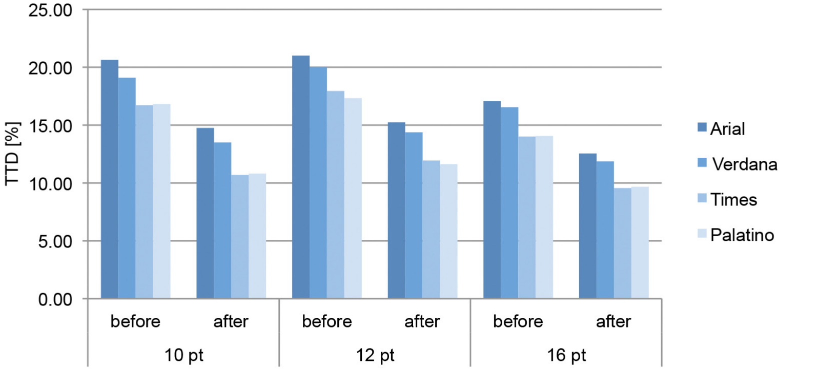

Figure 3: Average value of typographic tonal density (TTD) of tested typefaces in different sizes printed with Printer 1, before and after exposure

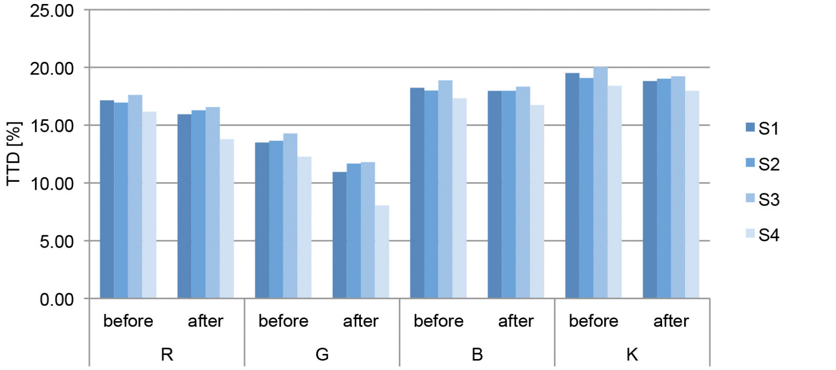

Figure 4: Average value of typographic tonal density (TTD) for R, G, B, K prints on different papers (S1–S4) printed with Printer 2, before and after exposure

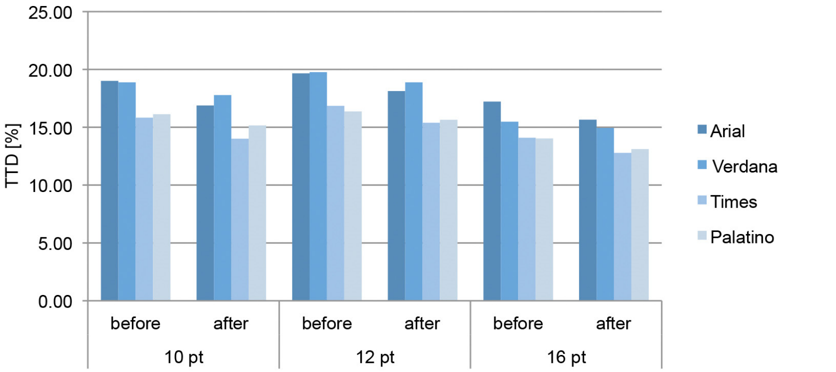

Figure 5: Average value of typographic tonal density (TTD) of tested typefaces in different sizes printed with Printer 2, before and after exposure

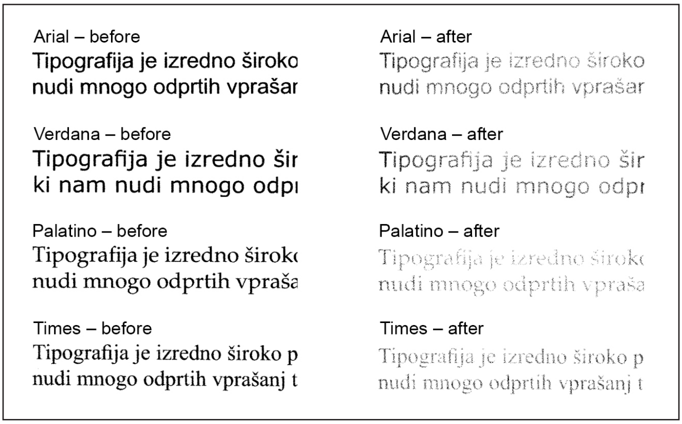

Figure 6: Sample of exposed typefaces in red, 10 pt in size, before and after exposure (S4, P1)

3.2 Influence of light on colorimetric properties

Tables 2 and 3 show the CIE L*a*b* parameters for the prints (R, G, B, K) of different intensity printed with different inkjet printers. The obtained results show that there are only minor differences among the samples and printers. The influence of a printer, i.e. ink, is even less pronounced as the values L*a*b* for similar samples are very close. A comparison of black (K) prints shows that slightly better results were obtained with P2, as they were less chromatic and exhibited lower values of lightness L*.

Figures 7 and 8 show the calculated colour differences (ΔE) on the printed samples after the exposure to xenon light. As it was expected, smaller colour differences are in general observed on the samples made with P2, which uses ink comprised of pigments. It is evident that blue samples of all intensities (B80, B60, B40) printed with both printers tend to fade much more than other prints (R, G, K). Blue prints are produced by mixing cyan and magenta. It is very likely that for both printers, cyan ink is based on copper phthalocyanine. For magenta ink, however, quinacridone or azo structures can be used, which exhibit only limited resistance to light [19, 21]. The smallest colour differences were established for black samples, regardless of the printer used, as in this case both printers use pigment-based inks. These results are in accordance with the measured differences in typographic tonal density values.

The colour prints (R, G, B) produced with P1 exhibit very poor resistance to light and the colour differences after the exposure exceed five units for the majority of prints (cf. Figure 7). Fading is again especially evident for blue and some red prints as the colour differences exceed even ten units (cf. Figure 7). This can be probably ascribed to poor light fastness of the magenta ink present in those prints. Fading is also pronounced with the prints of higher intensity (R80, B80, B60). In general, the influence of the substrate is not very evident. The results obtained on the recycled paper (S3) are comparable to those obtained for the other three office papers (S1, S2, S4). The smallest colour differences are observed at the prints on S2, which has the highest gloss, while the largest appear on S1, which has quite high porosity. Black prints, however, exhibit very good resistance to light, which is especially evident for the prints of higher intensity (K80), regardless of the paper used.

The fading resistance of colour prints (R, G, B) made with P2 is much higher in comparison with P1 and the colour differences after the exposure to light rarely exceed five units (B40 on S1, S3 and S4, B60 on S4). As with P1, also for the prints made with P2, poorer resistance to light is observed for blue and some red (R40) prints (cf. Figure 8). Generally, fading is less evident on the prints of higher intensity. The colour differences observed for black (K) prints are comparable to those for colour prints (R, G, B), as in this case all inks are based on pigments. The smallest colour differences were again observed on S2, whereas the largest were observed on S4.

		R			G			B			K		
		80%	60%	40%	80%	60%	40%	80%	60%	40%	80%	60%	40%
S1	L*	59.59	68.34	76.33	54.38	64.90	73.82	47.41	56.91	66.94	44.54	58.42	69.35
	a*	39.00	25.38	17.24	−39.32	−33.28	−21.96	−1.04	2.07	1.17	1.18	1.30	1.36
	b*	22.67	17.85	9.01	1.48	−0.94	−1.65	−36.51	−34.27	−29.68	−0.77	−2.95	−4.83
S2	L*	60.91	69.67	77.57	54.13	65.97	75.53	49.71	60.00	68.32	47.96	61.42	71.52
	a*	36.09	23.18	15.52	−37.23	−30.08	−18.40	−0.38	2.06	1.79	1.69	1.80	1.93
	b*	21.20	15.43	7.06	−1.76	0.22	−2.71	−34.19	−31.29	−27.22	−0.38	−2.79	−4.93
S3	L*	60.28	69.10	76.55	53.15	65.27	74.30	47.95	58.32	67.44	47.93	62.45	73.09
	a*	37.45	24.66	16.05	−37.98	−30.61	−19.43	−1.77	0.44	−0.10	1.02	0.92	0.85
	b*	23.24	19.33	12.54	0.10	3.98	3.32	−31.12	−26.13	−20.20	1.66	1.19	0.79
S4	L*	62.30	71.44	78.69	55.45	67.76	76.62	51.15	61.09	70.24	46.57	59.56	69.53
	a*	36.54	23.97	16.04	−37.06	−29.04	−17.63	−0.91	2.35	1.82	1.87	1.95	2.03
	b*	20.53	15.23	7.35	−2.77	−0.57	−1.55	−34.79	−31.40	−26.96	0.98	−1.58	−3.62

Table 2: CIE L*a*b* parameters of prints (R, G, B, K) with different intensity printed with printer P1 on different papers (S1–S4)

		R			G			B			K		
		80%	60%	40%	80%	60%	40%	80%	60%	40%	80%	60%	40%
S1	L*	60.61	68.47	76.30	61.28	68.92	77.96	45.82	54.82	67.55	39.86	51.20	66.65
	a*	48.59	33.93	19.82	−37.86	−30.18	−16.38	5.42	5.73	4.72	1.05	1.17	1.43
	b*	27.69	22.63	9.54	9.28	6.19	−2.46	−36.64	−35.57	−28.42	−0.34	−1.92	−4.15
S2	L*	61.29	68.51	77.05	62.24	69.64	78.36	47.10	56.10	68.01	41.45	51.68	66.89
	a*	47.16	34.30	19.14	−34.52	−26.56	−14.25	4.86	5.75	5.01	1.06	1.28	1.64
	b*	26.21	20.96	8.30	8.31	4.47	−3.36	−34.57	−33.31	−26.69	−0.40	−1.76	−4.29
S3	L*	60.87	68.27	76.18	61.68	68.93	77.53	45.74	55.41	67.46	40.50	50.85	65.66
	a*	48.26	34.41	19.06	−35.68	−28.27	−15.79	3.81	3.82	2.99	1.00	1.01	1.09
	b*	28.07	23.90	13.92	12.14	9.31	3.76	−31.51	−28.41	−19.90	1.55	1.29	1.16
S4	L*	63.25	70.83	78.74	64.54	71.75	80.10	49.32	58.54	70.60	43.27	53.77	69.65
	a*	45.81	32.29	18.35	−30.96	−23.90	−12.30	4.85	6.35	5.20	1.24	1.44	1.80
	b*	23.35	19.46	7.28	7.00	3.65	−3.64	−33.72	−31.79	−25.49	−0.80	−2.41	−4.81

Table 3: CIE L*a*b* parameters of prints (R, G, B, K) with different intensity printed with printer P2 on different papers (S1–S4)

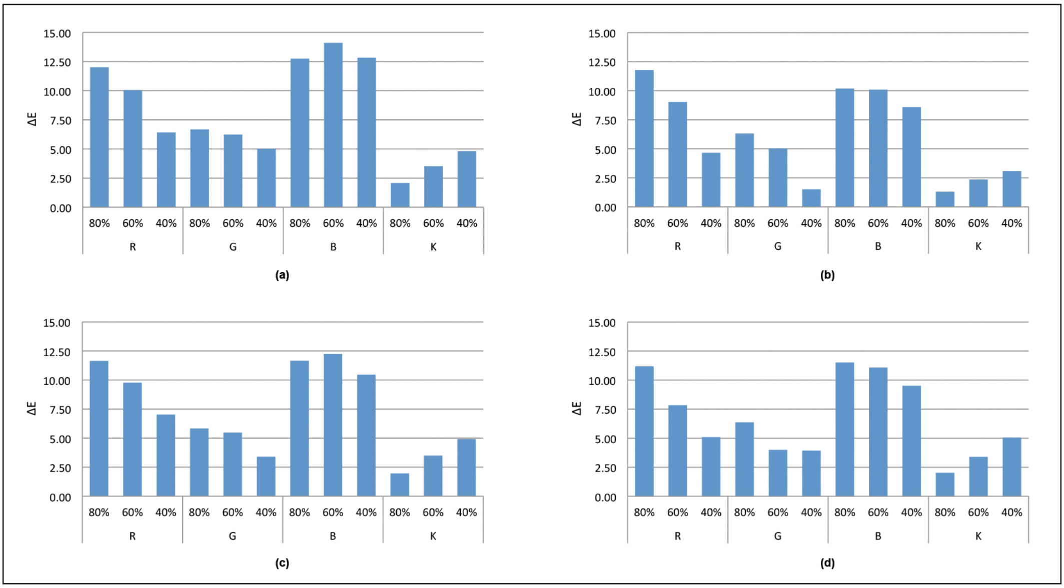

Figure 7: Colour difference (ΔE) on a) Sample 1, b) Sample 2, c) Sample 3 and d) Sample 4 printed with Printer 1

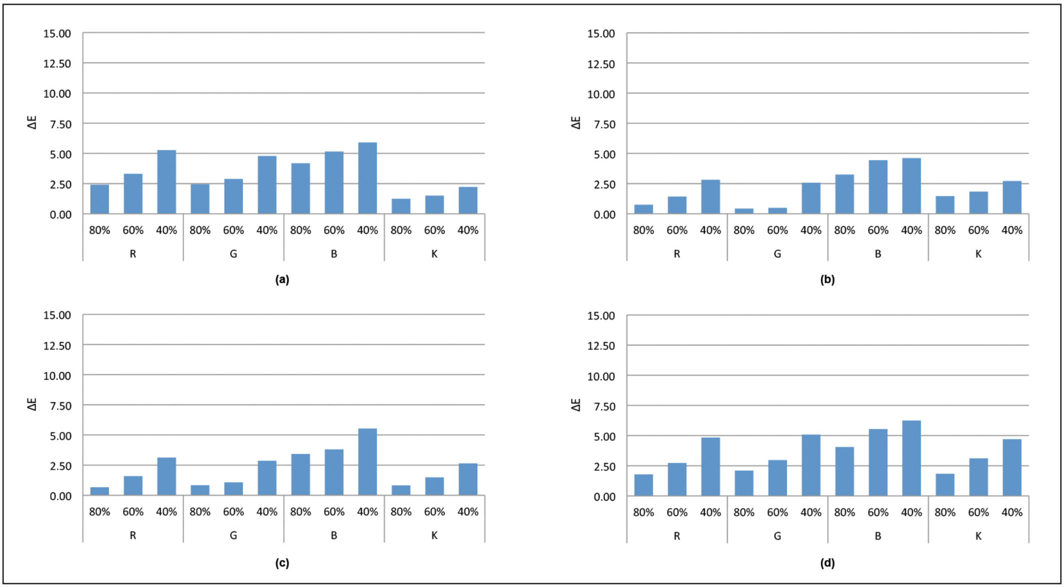

Table 8: Colour difference (ΔE) on a) Sample 1, b) Sample 2, c) Sample 3 and d) Sample 4 printed with Printer 2

4. Conclusions

The results of the study lead to the conclusion that it is necessary to consider the chosen typeface style and its size to ensure information permanence. Typefaces with thin strokes and big counter size are thus not recommended. Thin strokes and small adds, i.e. serifs, are evidently more sensitive to light. Special attention has to be paid at coloured prints (R, G, B). The strokes of typefaces should be thick enough, e.g. sans-serif. The obtained results reveal that small differences in paper quality are not of great significance for the resistance of prints to light, e.g. despite being recycled, Sample 3 showed good printability properties. More important, on the other hand, is the selection of a printer, the ink of which is either dye- or pigment-based. The results show that smaller changes in colour properties and frequently also in typographic tonal density occur on the prints made with inkjet printers with inks comprised of pigments. It was also established that the prints with lower intensity usually tend to fade more than the prints with higher intensity.

In order to ensure information permanence, attention should also be paid to the selection of proper typeface styles next to using inkjet printers with ink comprised of pigments rather than dyes. Since sans-serif typefaces were more resistant to light, it can be concluded that the usage of such typefaces is more appropriate for permanent documents.

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