

## L15 SUBJECTIVE AND OBJECTIVE EVALUATION OF RECOGNISABILITY OF BLACK CHARACTERS ON PAPER

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### Introduction

Visibility and recognisability of text is the key factor, influencing the information intake from printed media, billboards and other sources. As follows from several recently published papers, its importance is still increasing with the development of new technologies of spreading out the information (e. g., internet or cellular phone technology). On the other hand, a lack of attention is paid to the text visibility and recognisability, as only few published papers deal with an objective method for its determination/evaluation, respectively until present.<sup>1–9</sup>

The background/foreground colour contrasts, as well as the luminance of carrier are considered to be the key factors with significant impact on text visibility and recognisability. Further on, the visibility and recognisability of achromatic documents influences besides the previously mentioned also the following visual factors: letter size and style, text effects used, screen resolution, and, additionally, adaptability of reader/observer on the text displayed on screen.

The development of objective method for visibility and recognisability evaluation and prediction is of great importance. It can be later on applied for further paper quality controlling/improvement process, to affect the preferences of printing offices (to use paper of certain grades and luminance); for paper recycling processes optimization; deacidification, modification, coating, encapsulation, scission or different conservation technologies; effect of processes of deacidification of old books and archive documents; and last but not least, to improve the communication between paper-making and printing industry and their clients/customers.

In order to obtain the objective valuable method for visibility and recognisability evaluation, it is important to find unambiguous answers on the question of the dependence or mutual correlation between subjective assessment of visibility and recognisability and the objective foreground/background contrast measurement, keeping the letter size and style constant. Additionally, the impact of carrier ageing, e.g., paper acidic hydrolysis induced destruction, as well as the influence of modern developed deacidification and stabilization procedures applied for the historical/archival document conservation and protection<sup>10</sup>, on their visibility and recognisability is still not satisfactory proven and verified.

The aim of this work is to determine the influence of contrast between text character and background (foreground/background optical contrast) and other factors on monochromatic text visibility and recognisability and to present new valuable method of its evaluation from simultaneous comparative subjective (human observers) and objective (spectrophotometric) measurements of optical contrast. Moreover, we propose here the objective method for the determination of visibility and recognisability of documents and its prediction in aged documents in respect to all previously mentioned significant objective factors.

### Experimental

#### Samples Characterisation

Commercial white office paper Maestro was used in all experiments. Sets of randomly generated standard black colour letters of Latin alphabet (size, 12 pt; style, Times New Roman regular (Microsoft Office® 2003)) creating the strings of constant length, printed using commercially available colour printer, (nominal resolution, 600 DPI) were printed out on paper sheet. Standardized black letters are defined in CIE  $L^*a^*b^*$  system as follows:

$$L_c^* = 30.668, a_c^* = 0.714, b_c^* = -0.18 \quad (1)$$

#### Subjective Visibility and Recognisability Evaluation

##### Observers

Ten undergraduates of an average age of 20 years with standard visual acuity and correct colour recognisability without any previous experiences with such type of testing were used as observers. Five sets of randomly generated text strings of identical length were used during the measurement with one observer. The character of strings excluded the factor of potential learning process.

F G H I J T 3 Z Y V S F R E I K O 8 K D Y F G W Q O P V B M N K L 2  
K L T 2 U 3 E W Q Z Y P U V Y U O P M 8 S 9 5 4 7 W A D Y G C X B U  
P O U 2 R E 5 7 8 9 1 4 5 6 R B V Y X Z V U B K L F D S Q O U I J T D

**Fig. 1. An example of the text string used in visibility and recognisability tests. (Contrast: background 0 %  $B_{b,MS \text{ Word}}$ , text 100 %  $B_{b,MS \text{ Word}}$ ).**

Typical set of generated text string is shown on Fig. 1. Two trained observers moreover estimated the distinction in borders using the method of magnitude estimation as previously suggested in ref.<sup>1</sup>. Observers were tested to the ability to correctly recognize (read) 10 randomly selected letters from the generated strings for each contrast scale (Table I).

#### Evaluation of the influence of document contrast on its visibility and recognisability

Psychophysical method was used to measure the number and percentage of correctly recognized characters ( $R_s$ ) at the same background/foreground contrast of documents:

Observers were asked to recognize 10 randomly selected characters from different text strings for each contrast between text characters and background. The distance  $l_i$  (cm) between the observer and text was changed continuously either to the distance  $l_{100,i}$  at which still 100 % of the text was recognized correctly, or to  $l_{0,i}$ , with 0 % of correctly recognized letters. Using this approach, the dependence of correctly recognized letters on the distance for each colour contrast was obtained. The so obtained “absolute” individual visibility and recognisability functions  $R_{S,i} = f(l')$  was normalized, in order to minimize the influence of external factors (e.g., light direction, source or intensity). Each  $l_i$  value was related to the value of  $l_{100}$ , obtained for the text string written on 100% white background (0 %  $B_{b, MS Word}$ , Table I). The so-obtained values of  $l'_i$  were used for the contrast dependent visibility and recognisability evaluation.

### Objective Visibility and Recognisability Evaluation

The same text samples as utilised in subjective visibility and recognisability tests were analysed by commercially available spectrophotometer Minolta CR 200. CIE colour parameters  $L^*$ ,  $a$ , and  $b$  for both, text characters ( $L_C^*$ ,  $a_C$ ,  $b_C$ ) and for background ( $L_B^*$ ,  $a_B^*$ ,  $b_B^*$ ), using the cylindrically shaped gape collector (gape size, 3 mm) without any filters and software correction applications. From these values the colour difference  $\Delta E_{C-B}$  between the text and its background as a basic evaluation parameter was calculated using the following equation:

$$\Delta E_{C-B} = \sqrt{(L_C^* - L_B^*)^2 + (a_C^* - a_B^*)^2 + (b_C^* - b_B^*)^2} \quad (2)$$

### Statistical Analysis and Data Correlation

The dependencies of  $l'_i$  and  $\Delta E_{C-B}$  on text visibility and recognisability as well as the mutual correlation between these parameters were fitted to the proper mathematical function using the non-linear regression analysis. The statistical parameters of the calculation procedure (R squared, coefficient of determination and correlation, P) serve for the quality of correlation consideration.

### Results

Typical dependence of averaged visibility and recognisability on relative distance from an object, obtained for different background/foreground contrasts ( $\Delta E_{C-B}$ ) from typical observers, is depicted on Fig. 2. For the better visualization of the text recognisability dependence on foreground/background contrasts, the obtained dependencies for each contrast were averaged and the maximum achieved distance at which just the 100% successful recognisability was achieved ( $l_{100\%}$ ) at each contrast value was evaluated. As we have found, the continuous background “darkening” causes the gradual luminance decrease. We moreover found, that text visibility and recognisability increases significantly in the

Table I

A set of different background/foreground contrast,  $\Delta E$  values obtained from (2), and subjective evaluation of the same colour system. The different contrasts between background and printed text (foreground) were achieved using Microsoft Office Word® 2003 software grey scale, setting the ratio of black colour (Bb, MS Word) to 0 % (100 % white); 5 %; 10 %; 20 %; 30 %; 40 %; 50 %; 60 %; 70 %; 80 %; 90 %; 95 %; and 100 % (totally black), respectively, as it is listed below

Background shading set by MS Word® Software	Blackness $B_{b, MS Word} [\%]$	$\Delta E_{C-B}$	$\Delta E_{C-B}$ , visual evaluation
	100	0.0	negligible
F G H I J	95	6.1	significant
F G H I J	90	8.2	great
F G H I J	80	15.7	considerable
F G H I J	70	20.4	considerable
F G H I J	60	28.3	considerable
F G H I J	50	36.5	considerable
F G H I J	40	40.6	considerable
F G H I J	30	48.0	considerable
F G H I J	20	53.1	considerable
F G H I J	10	60.2	considerable
F G H I J	5	64.5	considerable
F G H I J	0	64.7	considerable

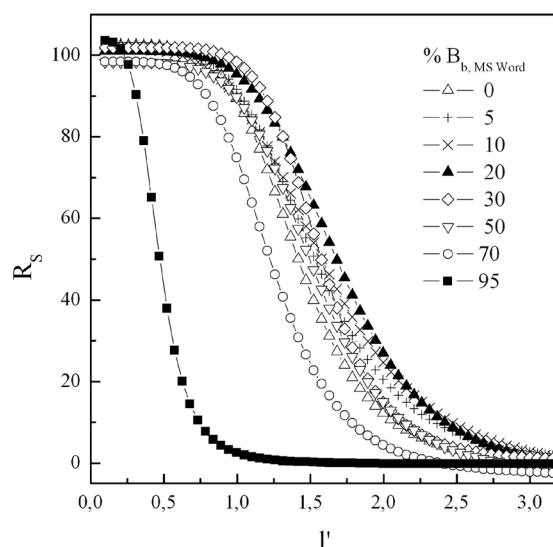


Fig. 2. The dependence of text recognisability ( $R_s$ ; %) on the relative distance from observer ( $l'$ ; m), evaluated from visual test for different colour contrasts  $B_{b, MS Word}$

range of  $B_{b, MS Word} \% <10-30>$ , in comparison to pure white background.

The further addition of black colour ( $\% B_{b, MS Word}$ ) into background does not influence the text visibility and reco-

gnisability in any way, as the maximum distance for 100% correctness of reading is in fact, the same as if the text is printed on white background (0 %  $B_{b, MS\text{Word}}$ ). As a result of additional darkening, the visibility and recognisability and correctness of text recognition dramatically decreases and at 95 %  $B_{b, MS\text{Word}}$ , which is in fact, almost pure black background of similar hue and saturation as the text in foreground, the correctness fallen down close to zero.

The dependence of visibility and recognisability on text background is better visible, when the relative distance,  $R_s$ , is plotted versus the foreground/background colour difference  $\Delta E_{C-B}$ , evaluated from spectrophotometric measurements, as it is clearly depicted on Fig. 3. for the same observer. The opinion that text recognisability is in linear dependence to the optical contrast, is widely spread out. In contrary to this assumption, we found that the dependence between the visual subjective recognisability/visibility and recognisability and optical contrast  $\Delta E_{C-B}$  is not linear in the whole range of  $\Delta E_{C-B}$ , as is finally clearly demonstrated on Fig. 3. (theoretical course 1). At lower  $\Delta E_{C-B}$  (up to 30%) the linearly growing dependence of visibility and recognisability on colour contrast is observed, while on the contrary at higher  $\Delta E_{C-B}$  the saturation of text visibility and recognisability is observed, or the visibility and recognisability slightly decreases.

From the data presented on Fig. 3., the region of improved recognisability might be delimited. At optical contrast e.g.,  $\Delta E_{C-B} = 64.7$ ,  $L_B^* = 93.2$  and  $B_{b, MS\text{Word}} = 0\%$  the value of relative visual recognisability/visibility and recognisability reaches the value  $R_s = 0.983$ . If the optical contrast decrease of e.g., to  $\Delta E_{C-B} = 53.1$ , the  $R_s$  value increased to the value of 1.02. It means that in spite of lowered optical contrast between the foreground text and background, reader/observer is able to recognize the printed character from the longer distance than at higher optical contrast.

Data obtained in subjective visibility and recognisability tests served for the re-calculation and transformation of optical

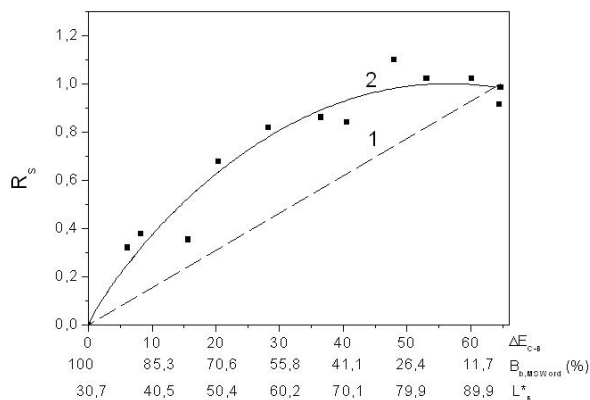


Fig. 3. The representative dependence of text visibility and recognisability (expressed as  $R_s$ ) on the colour difference ( $\Delta E_{C-B}$ ), evaluated from spectrophotometric measurements, whiteness of background ( $L_B^*$ ) and blackness ( $B_{b, MS\text{Word}}$ ; %). 1 – theoretical course, 2 – measuring course

colour difference ( $\Delta E_{C-B}$ ) on the objective optical-device predictable visual recognisability/visibility and recognisability, expressed by the following mathematical equation:

$$R_s = \left[ 1 - \left( \frac{\Delta E_{C-B} - 56.4}{56.4} \right)^2 \right]^{0.87}, \quad (3)$$

which correlates well with experimental data. As follows from the data presented, change in relative recognisability is significantly dependent on the initial optical contrast, i.e. on the optical contrast of non-modified document.

## Conclusions

Based on the results presented, we can conclude that the visibility and recognisability of text printed on white background (i.e., freshly produced paper just after the industrial whitening), is even worse than those, printed on grey or shaded papers. This fact can find effective application in paper recycling industry, which is nowadays of growing importance, with one of the key problems of recycled paper whitening without the influence on its mechanical or physical properties.

The evaluation of text visibility and recognisability of printed documents based on both subjective and objective assessment is presented in this paper for the first time. Objective easy-to-use methods of paper visibility and recognisability evaluation based on tristimulus values measurements are presented, based either on the relative visibility and recognisability and optical contrasts or on their relative indexes dependencies, respectively. As follows from results presented, the dependence of recognisability and visibility of printed text on respective background optical contrast has not the linear character, i.e., the higher optical contrast (“white background”) can even make the visibility and recognisability of text worse than that printed on lower contrast background.

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## REFERENCES

- Legge G., Rubin G., Leubker A.: 27, 1165 (1987).
- Knoblauch K., Arditi A., Szlyk J.: J. Opt. Soc. Am. A 7, 1976 (1990).
- Scharff L. F. V., Hill A. L.: Optic Express 6, 81 (2000).
- Paterson D.G., Tinker M.A.: J. Appl. Psychol. 30, 454 (1946).
- Silver N. C., Braun C. C.: Safety Sci. 16, 615 (1993).
- Leung C. C., Chan K. S., Chan H. M., Tsui W. K.: Pattern Recogn. Lett. 26, 769 (2005).

7. Öquist G., Goldstein M.: *Interact. Comp.* 15, 539 (2003).
8. Pescio S., Mattiello M. L. F., Álvarez R.: AIC 2004 Colour and Paints, Interim Meeting of the International Colour Association, Proceedings, 47 (2004).
9. Blackwell H. R., Blackwell O.: *Effects of lighting upon visual performance*. Columbus, Ohio State University, Illuminating Engineers Research Institute (1980).
10. Polovka M., Polovková J., Vizárová K., Kirschnerová S., Bieliková L., Vrška M.: *Vib. Spec.* 41, 112 (2006).