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Effect of Lightness on Blackness Preference of Black Fabrics

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ABSTRACT

In this paper, the effect of lightness on blackness preference of 216 black fabrics prepared by printing method is investigated. Ten observers including five males and five females are first asked to rank order black fabrics with the same lightness values according to their preference. In the next step, observers are asked to define their blackness preference for blacks with different L values. Results show that while there are some neutral black fabrics, observers mostly prefer bluish-cyanish blacks. Besides, samples with the higher values of lightness and chroma are not preferred by observers especially when their hue angles lie in the first quarter of the hue area, i.e., 0-90^o. Meanwhile, samples with the lowest lightness values are not preferred by most of observers because of their high chroma values. This achievement proves that lightness is not the only colorimetric attributes which influences blackness preference. Prog. Color Colorants Coat. 8(2015), 11-24 © Institute for Color Science and Technology.*

1. Introduction

The color world is including of chromatic and achromatic colors. In a fully gray scale description, the general imagination of perception of achromatic colors, i.e., blacks, whites and grays, is based on their differences in lightness values. In fact, it seems that these neutral colors are distributed over the lightness axis of different color spaces while they benefitted from different hues and tints in the real world [1, 2].

The attribute of tint factor of neutral colors will become more important when people want to select their preferred whites, blacks and grays. For instance, all white papers, fabrics, paints and even teeth are perceived as whites while visually they are not the same. On the other hand, people may prefer different tints based on the applications and the cultural backgrounds. For example, people may prefer the

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bluish whites for fabrics while they may never select this tint effect for their teeth [3, 4].

Among the neutral colors, the whites have been investigated much more thoroughly than the blacks. This may be due to the application of white samples in important industries like textiles and papers [5-8].

In contrary to whites, black samples have not been studied systematically. There are just a few researchs which have investigated black samples spectrally [2, 9-11] and colorimetrically [11-17]. One of the first studies in blackness perception was done by Kihara *et al*. [11]. In order to investigate the pure blackness of fabrics applied in women's formal dresses, they tried to find a relationship between the blackness perception and the structure properties of fabrics. They showed that among the mechanical properties of fabrics, thickness is the only factor which influences the perceived blackness [11]. In order to introduce a novel method for evaluating of blackness perception, Asano *et al*. investigated the results of visual evaluations of different black fabrics with various structures by introducing some bipolar attributes, i.e., blackness (black/not black), formalness (formal/informal), brightness (bright/not bright), to observers as visual assessment criteria. They showed that different black fabrics with various textures and fibers cause different blackness perception while fabrics have the same lightness [11]. Westland *et al.* tried to represent a blackness index to evaluate black papers prepared by printing. Among the four metrics proposed based on the CIE whiteness formula, an index which was introduced in CIELAB color space showed the best correlation with the results achieved by visual evaluation experiments [5]. Lan Tao and her coworkers [12, 13] investigated the effect of hue on perceived blackness based on the blackness preference and perception. They asked observers to visually assess ten darkest Munsell color samples with the same chroma and lightness as well as three neutral samples; one with the same lightness as Munsell color samples, the second one darker and the third one lighter than Munsell color samples. Results showed that while observers judge the darkest neutral sample as the nearest sample to the pure black, they prefer the bluish black samples [12, 13]. In the next research, Lan Tao and her coworkers investigated the effect of lightness and chroma on blackness perception and preference of two groups of Chinese and English observers. Results showed that in contrary to English observers, Chinese preferred darker blacks while the nationality does not influence the blackness perception. In other words, both Chinese and English observers evaluated the darkest neutral samples as the nearest samples to the pure black [12, 14]. Clonts and her coworkers investigated the effect of colorimetric attributes on blackness perception of different black samples, i.e., Munsell paper samples, woolen fabrics and acrylic fabrics. They presented two models for ranking and rating of blackness based on the visual evaluations [15, 16]. The proposed ranking model considered just the hue angle of blacks and the rating index was based on the chroma and hue angle of black samples. Clearly, the lack of lightness which is one of the most important factors in blackness perception could be observed in both ranking and rating models proposed by Clonts *et al*. Besides, none of two rating and ranking models simultaneously consider all colorimetric attributes, i.e., L*, C* and hue angle. The mentioned week points are related to the selection of a limited number of black samples with the same lightness or chroma values which is not true, realistically. In other words, there are various black samples with different colorimetric properties in real world. A blackness index should be able to respond to the results of real observations while it seems that the two ranking and rating models proposed by Clonts *et al*. do not meet this requirement. Recently, Jafari and coworkers [17] investigated the colorimetric boundaries of blacks based on the perceived blackness. They showed that black fabrics with high lightness values and low chromas as well as blacks with low lightness values and high chromas are perceived as blacks by majority of observers if samples benefit from greenish to bluish tints. Besides, samples with high lightness and chroma values will not be assessed as blacks if their hue angles did not lie in the third hue area, i.e., 180-270^{o} [17].

As mentioned earlier, the general expectation of blackness perception is based on its lightness value. In other words, one seems that the perceived blackness would increase only by decreasing the lightness values. This paper tries to investigate the effect of lightness on blackness preference by performing the visual assessment experiments on two sets of black fabrics, i.e., black samples with the same and various lightness values.

2. Experimental

2.1. Sample preparation

In order to prepare black samples with different colorimetric properties, different concentrations of 4 colored pigments, i.e., red, green, blue and yellow in addition to the black pigment were used. The routine textile pigment printing technique was applied on the plain woven cotton fabrics. In this way, different mixtures of colored pigments and black pigment, i.e., binary, tertiary, quadric and quintuplet were applied in the printing paste consisting oil/water emulsion, ammonium sulfate as well as acrylic binder to print fabrics. Since there is no index to confirm the blackness property of prepared fabrics, the low lightness and chroma values of samples were considered as the blackness criteria. In this way, the percentages of the applied pigments in printing recipe were changed according to the achieved colorimetric properties of samples which were prepared according to the last printing recipe. Therefore, by controlling the colorimetric attributes during sample preparation, 216 black fabrics with different hues were achieved while benefitted from low lightness and chroma values. Table 1 shows the color indices and the supplier of applied pigments.

A reflectance spectrophotometer called Spectraflash from Datacolor was used to measure the reflectance spectra of black samples in the visible range from 400-700 nm by 10 nm intervals. The measurement geometry was d/8^{o} and the specular reflectance was included. Based on the measured reflectance spectra, the CIEXYZ tristimulus values of black samples were then calculated under D65 standard illuminant and CIE1964 standard observers. Figures 1a and 1b show the distribution of black samples over a*b* and C*L* diagrams of CIELAB and CIELCH color spaces, respectively. The distribution of black fabrics over the quadruplet areas of hue (Figure 1a) indicates that the black samples benefitted from different hues and tinting factor. Besides, Figure 1b shows that the prepared black samples have different levels of lightness (in order of 17.64 to 23.94) while their chroma values vary between 0.04 and 4.16.

2.2. Grouping of blacks based on lightness

In order to investigate the effect of lightness on blackness preference of 216 black fabrics, it was decided to group black samples according to their lightness values. By considering 1 interval steps of lightness, seven groups of blacks were formed in seven levels of lightness (1st level: 17≤L*<18, 2nd level: 18≤L*<19, 3rd level: 19≤L*<20 and so on), consequently, there were 6, 40, 60, 45, 40, 20 and 5 black samples in each group, respectively.

Table 1: The generic and the commercial names as well as the supplier of pigments used in printing process.

Commercial name	Supplier	Generic name
Imperon Black FBB	Dystar	Pigment Black 7
Imperon Blue K-RR	Dystar	Pigment Blue 15
Imperon Green K-G	Dystar	Pigment Green 7
Imperon Yellow K-2G	Dystar	Pigment Yellow 14
Imperon Red K-GC	Dystar	Pigment Red --

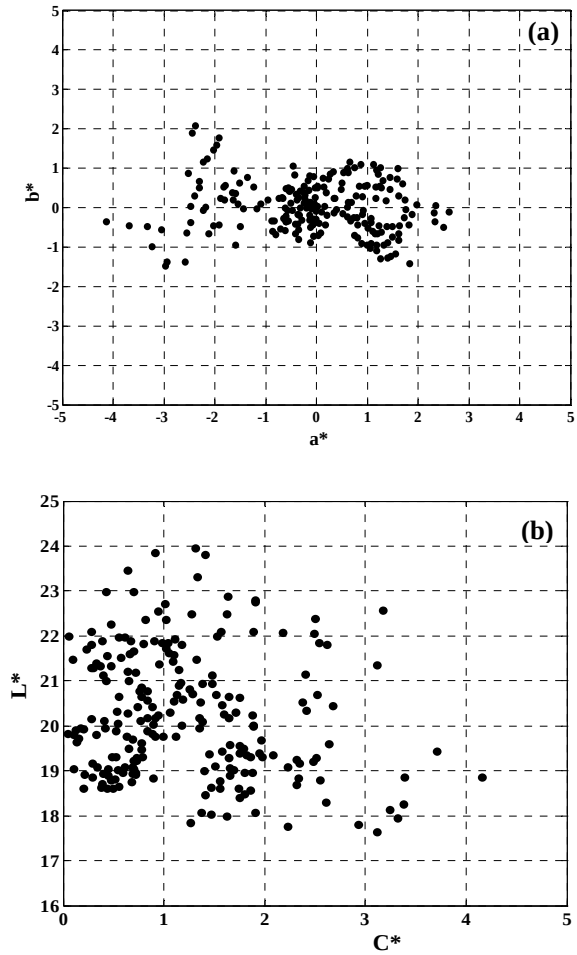

Figure 1: (a): a*b* and (b): C*L* scatter plots of 216 black fabrics.

2.3. Visual assessments

Ten observers including five females and five males in the range of 21 to 27 years old with the mean value of 23.8 years old attended in visual assessment experiments while the average age value of females (23.4) was less than males (24.2). The Ishihara test was first used to examine the normal color vision of participants. A light booth with a D65 standard illuminant simulator was used for visual evaluations. Since the samples have been cut in a size of 3×3 cm^2, observers were asked to evaluate blacks in a distance of 17 cm to fulfill the setup of CIE1964 supplementary standard observer. Before visual assessments, observers were treated to the concepts of blackness and preferred black. The visual evaluation experiment of black fabrics was done in two steps. First, the black samples of each group corresponding to a specific lightness level were randomly presented to the observers to rank order specimens according to their preference from minimum to maximum attribute of blackness. In this way, seven groups of blacks with seven levels of lightness values were rank ordered and the average of the ranks assigned by ten observers were considered as the scale values of blacks and showed the order of blackness preference. Then, the three blackest samples of each lightness level were extracted. In this way, 21 most preferred blacks were chosen from seven groups of blacks corresponded to the seven levels of lightness. For the second step of visual assessment experiment, the 21 selected blacks were randomly presented to 10 observers to rank order them according to their preference once again. Clearly, in the first step observers evaluated samples in a group of blacks with the same lightness values, while in the second step they assessed blacks with different levels of lightness.

3. Results and discussion

3.1. Assessment of blacks with the same lightness

As mentioned before, it was first decided to assess blacks with the same lightness values. In this way, seven groups of black fabrics were formed and assessed separately by observers. Finally, the most preferred three blacks were extracted from each lightness level. Figures 2 to 8 show the a*b* and the C*L* scatter plots of 7 groups of black fabrics in different lightness levels. In these figures, the most preferred three blacks in each lightness category are presented by stars. Table 2 demonstrates their colorimetric specifications. It is noticeable that the rank 3 in each row shows the most preferred black in each lightness level.

Figures 2 to 8 and Table 2 show that while there are black samples with lower chroma values, observers mostly prefer blacks with bluish-cyanish tints. As example, for black samples with the lower lightness values (L*≈ 17 to 21), irrespective of the high chroma values, there is at least one cyanish-bluish black sample among the most preferred blacks. In the other words, among black samples with nearly the same lightness values, the most neutral one is not necessary the most preferred black. For instance, the sixth row of Table 2 shows that among 20 black fabrics with approximately the L* value of 22, samples 34, 47 and 113 are selected by observers as the most preferred blacks. Among these three selected blacks, sample 113 is the most preferred one. In fact, while sample 34 is nearly a neutral black (C*=0.05), it is not selected as the most preferred black among the blacks with nearly the same lightness values.

It is noticeable that regarding to the limited number of samples in groups 1 and 7 with the lowest and highest lightness values, the achieved evaluation results may be subjective and the results for these groups must be interpreted cautiously.

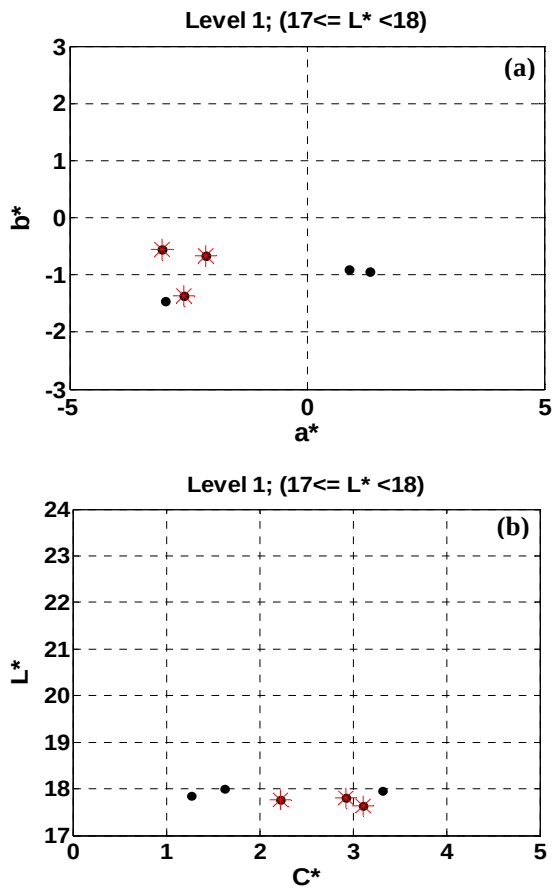

Figure 2: (a): a*b* and (b): C*L* scatter plots of 6 black fabrics rank ordered in the 1st L* category. The red stars show the three most preferred blacks in this group.

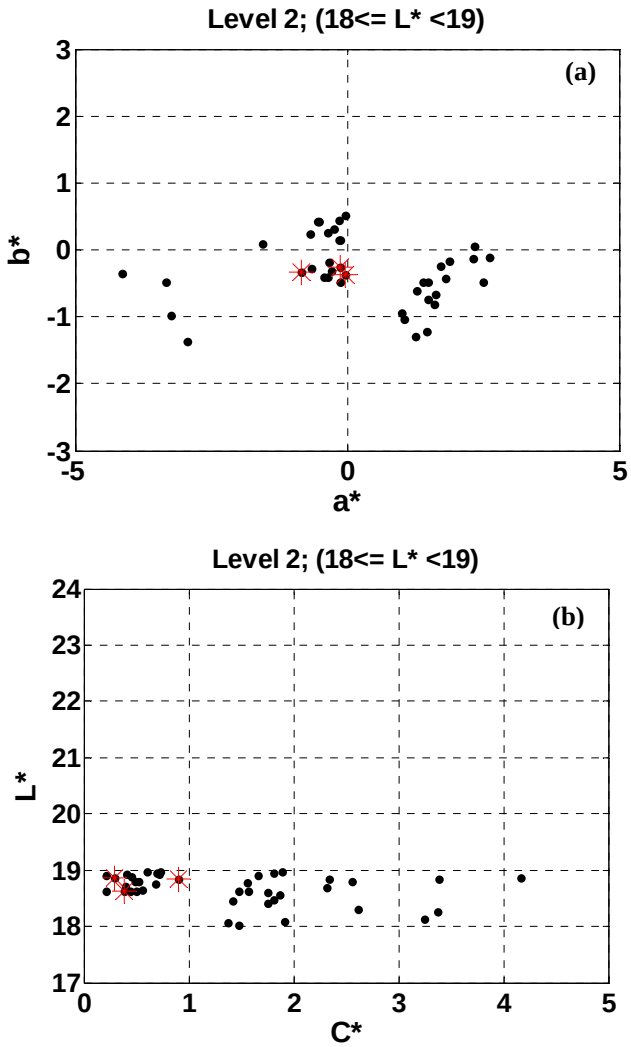

Figure 3: (a): a*b* and (b): C*L* scatter plots of 40 black fabrics rank ordered in the 2nd L* category. The red stars show the three most preferred blacks in this group.

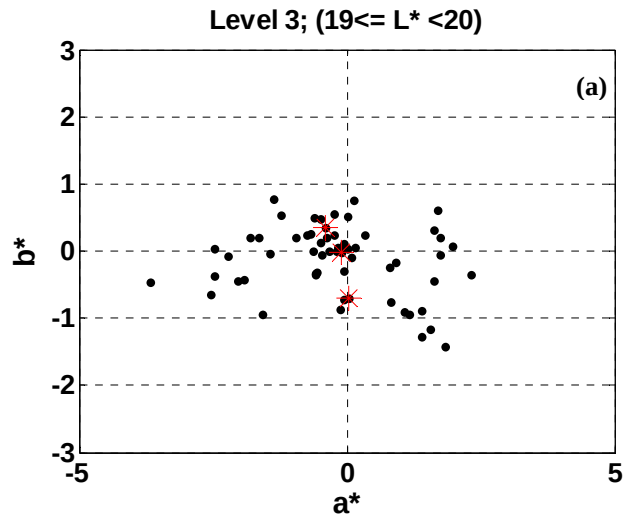

Figure 4: (a): a*b* and (b): C*L* scatter plots of 60 black fabrics rank ordered in the 3rd L* category. The red stars show the three most preferred blacks in this group.

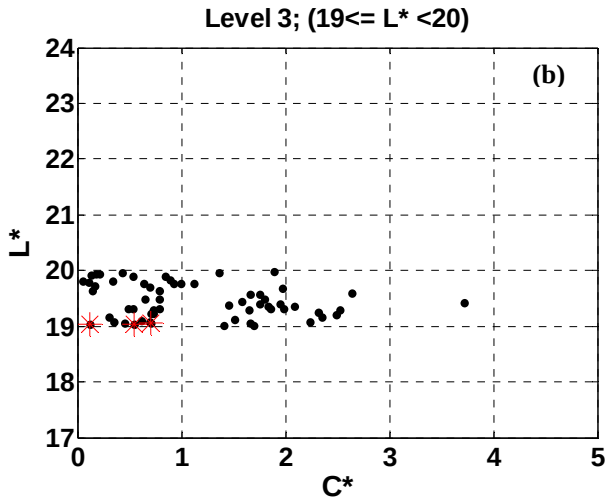

Figure 4: Continued.

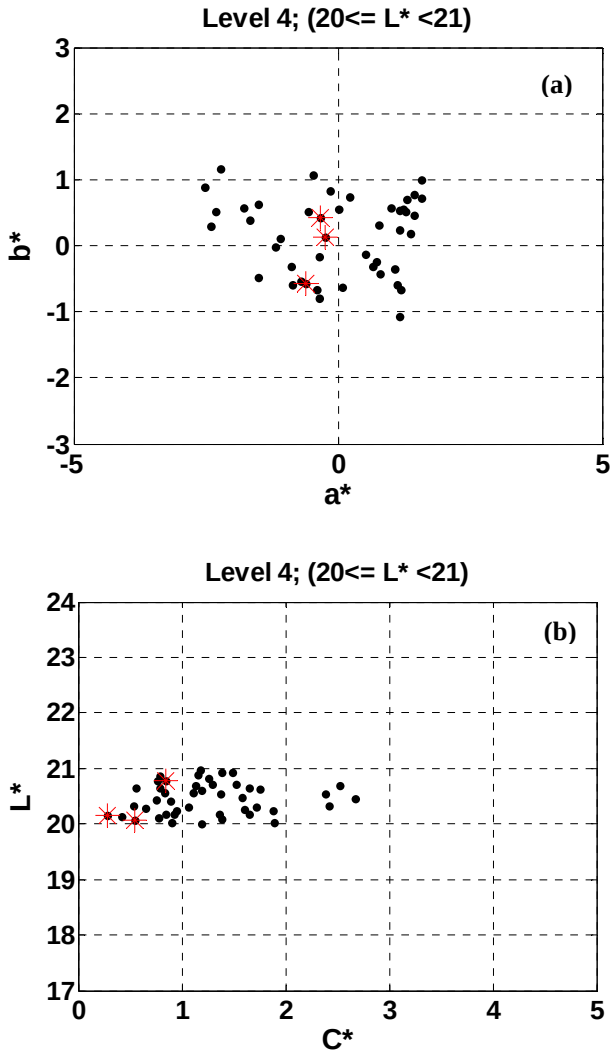

Figure 5: (a): a*b* and (b): C*L* scatter plots of 45 black fabrics rank ordered in the 4th L* category. The red stars show the three most preferred blacks in this group.

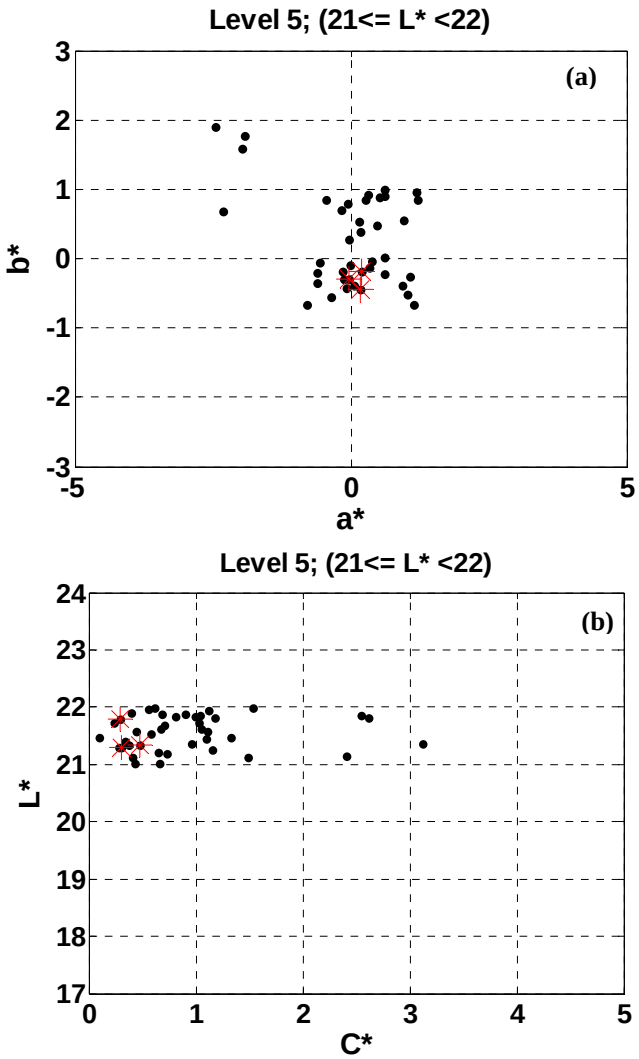

Figure 6: (a): a*b* and (b): C*L* scatter plots of 40 black fabrics rank ordered in the 5th L* category. The red stars show the three most preferred blacks in this group.

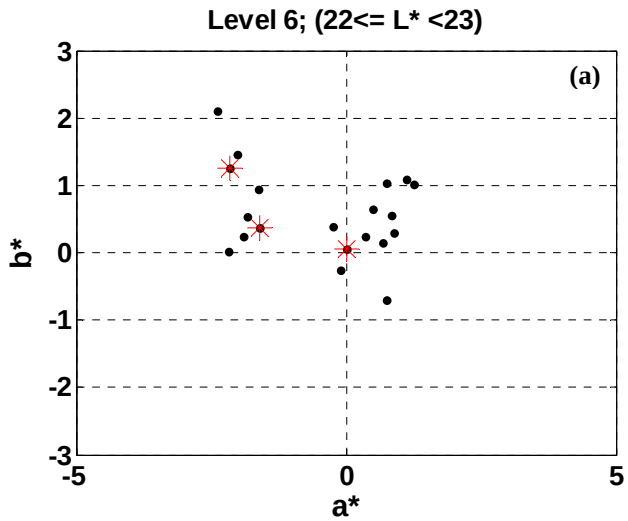

Figure 7: (a): a*b* and (b): C*L* scatter plots of 20 black fabrics rank ordered in the 6th L* category. The red stars show the three most preferred blacks in this group.

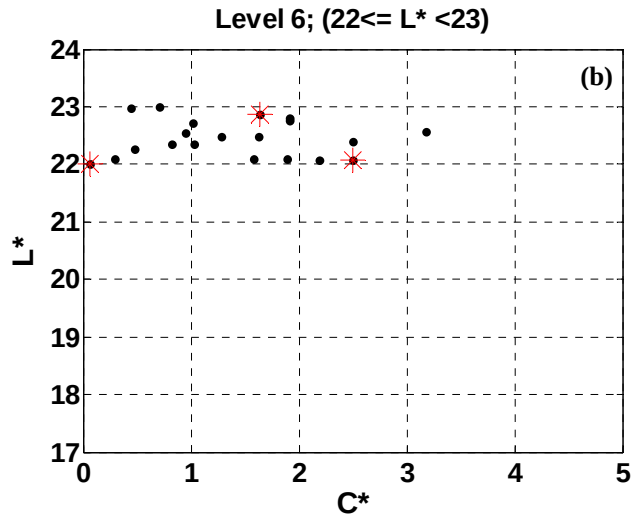

Figure 7: Continued.

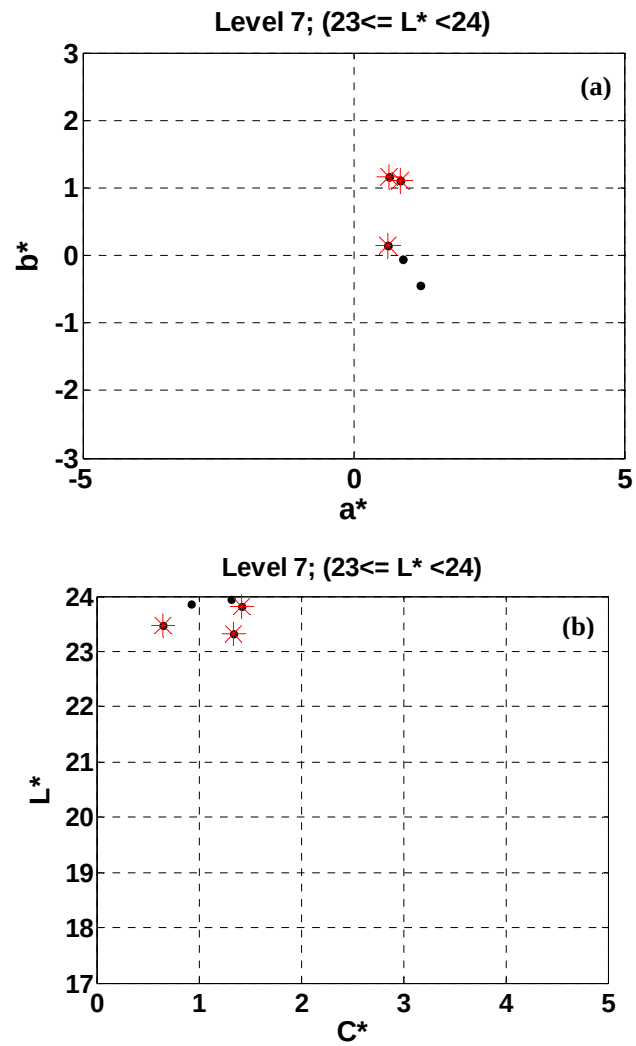

Figure 8: (a): a*b* and (b): C*L* scatter plots of 5 black fabrics rank ordered in the 7th L* category. The red stars show the three most preferred blacks in this group.

Table 2: The colorimetric attributes of the most preferred blacks corresponding to different lightness levels.

L* level	Rank	# of Sample	L*	a*	b*	C*	Hue angle^{o}
1: (17≤L*<18)	1	28	17.80	-2.59	-1.36	2.92	207.78
	2	88	17.64	-3.06	-0.55	3.11	190.22
	3	71	17.77	-2.12	-0.66	2.22	197.17
2: (18≤L*<19)	1	96	18.84	-0.83	-0.32	0.89	201.27
	2	84	18.86	-0.13	-0.26	0.28	243.57
	3	83	18.62	-0.03	-0.37	0.37	265.45
3: (19≤L*<20)	1	177	19.03	-0.41	0.35	0.54	139.35
	2	23	19.05	0.03	-0.69	0.69	272.45
	3	179	19.04	-0.10	-0.02	0.11	193.09
4: (20≤L*<21)	1	9	20.79	-0.61	-0.57	0.84	222.84
	2	126	20.07	-0.33	0.42	0.54	128.18
	3	73	20.15	-0.24	0.12	0.27	153.11
5: (21≤L*<22)	1	21	21.29	-0.02	-0.29	0.30	265.53
	2	22	21.34	0.17	-0.44	0.47	291.46
	3	14	21.80	0.20	-0.19	0.28	317.39
6: (22≤L*<23)	1	34	22.00	0.01	0.05	0.05	72.58
	2	47	22.88	-1.59	0.38	1.63	166.66
	3	113	22.06	-2.16	1.25	2.49	149.85
7: (23≤L*<24)	1	51	23.46	0.63	0.14	0.64	12.88
	2	160	23.81	0.87	1.11	1.41	51.72
	3	159	23.31	0.65	1.17	1.33	60.89

3.2. Assessment of blacks with different lightness

In step 2, the most three preferred black samples extracted from different lightness levels were considered as a group and randomly presented to observers to rank order these 21 blacks according to their preference from minimum to maximum. The average assigned ranks were considered as the scale values of black samples while the lower values indicate the minimum preference of observers in blackness perception. Figure 9 shows the scale values of rank ordered black samples. The x-axis shows the number of rank ordered samples while the y-axis indicates their corresponding scale values. The vertical lines in Figure 9 show the distribution of assigned ranks of 21 black

fabrics according to the observers, where the average, minimum and maximum of assigned ranks are also demonstrated. Table 3 shows the colorimetric attributes as well as the average assigned ranks (scale values) of 21 black samples. According to Figure 9 and Table 3, samples 159 and 83 with the scale values of 2.8 and 19.6 are respectively assessed as samples with the minimum and maximum preference of blackness from the observers' viewpoint. In the other words, samples are arranged based on their black preference from the left to the right sides of x-axis. In order to schematically compare the colorimetric attributes, the variation of L*, C* and the hue angles of rank ordered black fabrics are shown in Figures 10, 11 and 12, respectively. The vertical axes present the colorimetric properties and the horizontal axes show the number of rank ordered black samples.

According to Figure 9 and Table 3, samples which were fewer preferred by observers as well as those which mostly preferred (samples in both sides of Figure 9) were rank ordered with less standard deviations than those located in middle part of Figure 9. In other words, observers had more agreement for assigning the ranks to the least and the most preferred blacks.

Figure 10 shows the lightness values of 21 rank ordered black samples. According to Figure 10, except samples 28, 88 and 71, there is nearly a reverse relationship between L* values and blackness preference. In fact, as it is expected, observers' preference increases by decreasing the lightness values of black samples. The question is why samples 28, 88 and 71 with the lowest L* values (L* ≈ 17) were not perceived as the most preferred blacks among the 21 black samples? Table 3 and Figure 11 show that irrespective of the lowest L* values, the mentioned specimens have the highest chroma values which amplify their tint effect. Therefore, lightness is not the only colorimetric attribute which influences the blackness preference. On the other hand, according to Table 3 and Figure 11, sample 34 with the C*≈0 was assessed as the 5th preferred black among the 21 black samples. Regarding to the definition of ideal blacks (L*=0 and C*=0), it was expected sample 34 to be evaluated as the most preferred black or even one of the most preferred blacks with higher ranks. Considering the L* value of sample 34 (L*= 22.00), it becomes possible to explain why this neutral black sample has been evaluated with low degree of blackness preference. Besides, Figure 12 and Table 3 represent that the most three preferred black samples (179, 84 and 83) with low lightness (18<L*≤19) and chroma (C*<0.4) values, are located in the third hue area. Whereas, the worst black samples, i.e. specimens 159, 160 and 51, belong to the first hue area. In other words, the reddish-yellowish tint is not the observers' hue preference in blackness perception.

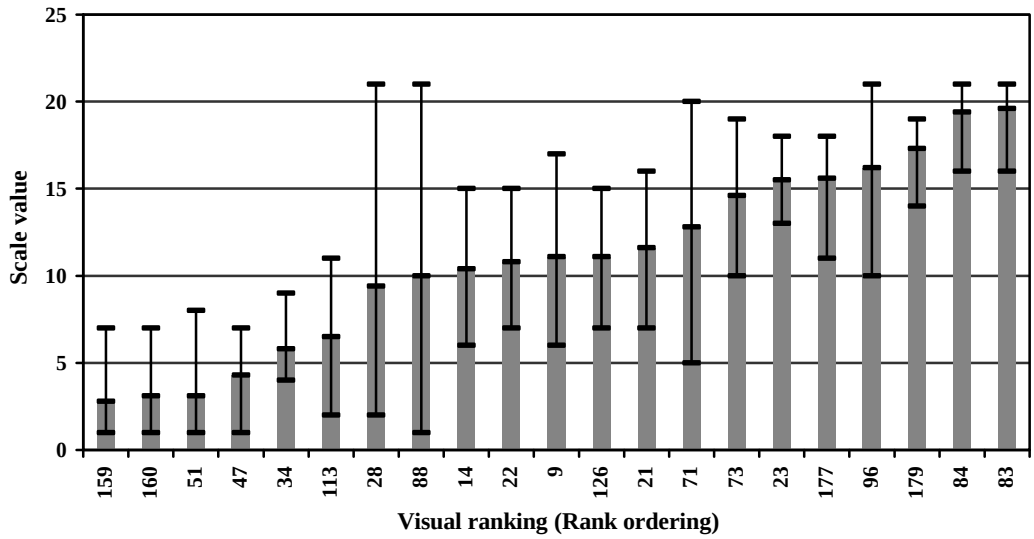

Figure 9: The minimum, maximum and mean values (scale value) of assigned ranks of 21 black fabrics with different lightness values. The x-axis indicates the samples code. Based on the values shown in y-axis, the blackness preference of the observers increases from left to right.

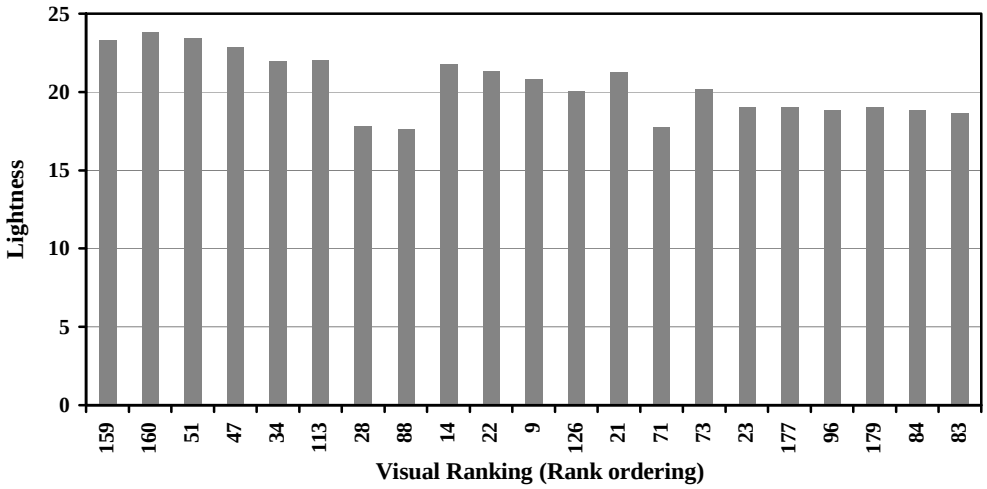

Figure 10: The lightness values of 21 visual rank ordered black fabrics .

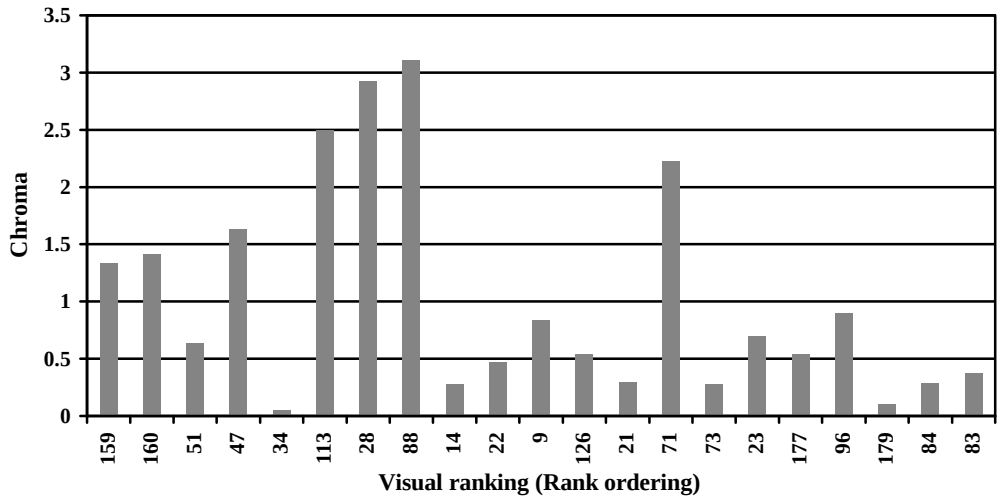

Figure 11: The chroma values of 21 visual rank ordered black fabrics.

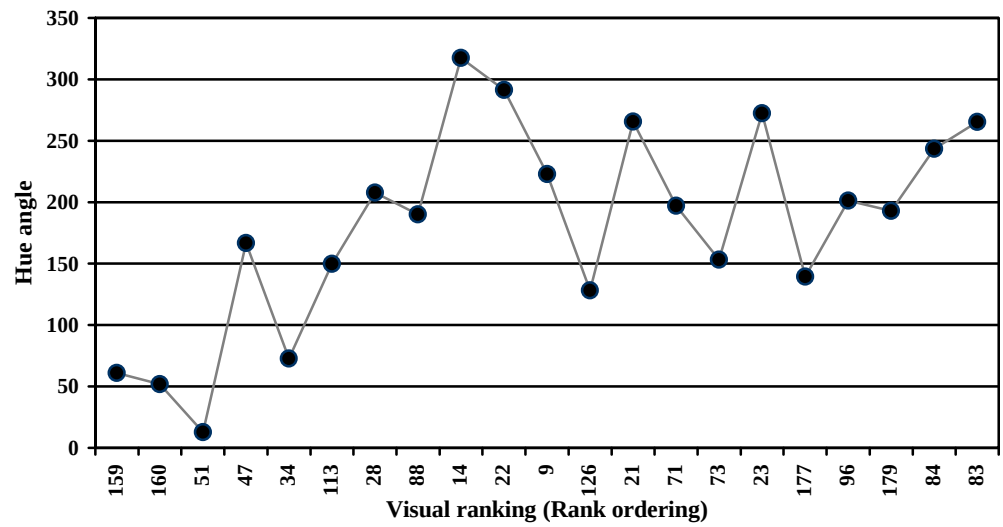

Figure 12: The hue angles of 21 visual rank ordered black fabrics.

Table 3*:* The colorimetric specification as well as the scale value of 21 visually rank ordered black fabrics.

# of Sample	Scale value	Standard deviation	L*	a*	b*	C*	Hue angle^{o}
159	2.8	2.04	23.31	0.65	1.17	1.33	60.89
160	3.1	1.72	23.81	0.87	1.11	1.41	51.72
51	3.1	2.38	23.46	0.63	0.14	0.64	12.87
47	4.3	2.11	22.88	-1.59	0.38	1.63	166.66
34	5.8	2.04	22.00	0.01	0.05	0.05	72.59
113	6.5	3.10	22.06	-2.16	1.25	2.49	149.85
28	9.4	6.29	17.80	-2.59	-1.36	2.92	207.78
88	10	6.77	17.64	-3.06	-0.55	3.11	190.22
14	10.4	2.46	21.80	0.20	-0.19	0.28	317.39
22	10.8	2.97	21.34	0.17	-0.44	0.47	291.46
9	11.1	3.48	20.79	-0.61	-0.57	0.84	222.84
126	11.1	3.21	20.07	-0.33	0.42	0.54	128.18
21	11.6	2.95	21.29	-0.02	-0.29	0.30	265.53
71	12.8	5.59	17.77	-2.12	-0.66	2.22	197.17
73	14.6	2.91	20.15	-0.24	0.12	0.27	153.11
23	15.5	1.84	19.05	0.03	-0.70	0.69	272.45
177	15.6	2.59	19.03	-0.41	0.35	0.54	139.35
96	16.2	4.02	18.84	-0.83	-0.32	0.89	201.27
179	17.3	1.70	19.04	-0.10	-0.02	0.11	193.09
84	19.4	1.50	18.86	-0.13	-0.26	0.29	243.57
83	19.6	1.58	18.62	-0.03	-0.37	0.37	265.45

4. Conclusions

The blackness preference of 216 black fabrics was evaluated by ten observers. The visual assessments were performed in two steps, i.e., for blacks with the same lightness values and for the most preferred blacks with various colorimetric properties. Results showed that in contrary to the ideal black definition, observers preferred bluish-cyanish blacks though there were some neutral samples among the black fabrics. Besides, while there are a reverse relationship between the lightness and the blackness preference of black fabrics, the darkest samples with the high chroma values were not preferred by most of the observers. Meanwhile, among the samples with high lightness and chroma values, observers preferred the bluish-cyanish

blacks. Finally, observers had more agreement for assigning the ranks to the reddish-yellowish blacks with less blackness preference as well as those with most blackness preference (bluish-cyanish blacks).

5. References

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