Blackness: Preference and Perception

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Abstract

Despite the importance of black there have been relatively few studies into blackness perception; by contrast a great number of equations have been published over the last 100 years that attempt to predict perception of whiteness [1,2]. In order to understand the different series of black color, the assessment of blackness will be discussed in this experiment. In the psychophysical experiment, comparative studies on color perception (which of two black samples observers considered to be closest to a pure black) and color preference (which of two black samples observers preferred) were carried out. All color samples were evaluated by hue and analysis carried out based on gender and nationality (Chinese and UK). No effect of culture was found for blackness perception; however, for blackness preference some significant cultural effects were observed.

Introduction

Many black inks are made by mixing colored dyes or pigments and can have an evident hue. Therefore, there are slight hue differences between blacks although they look rather similar. It is interesting to consider, for a range of blacks of varying hues, which black would be preferred or which black would be considered to be a 'better' black; this latter subjective quality may be important, for example, for the design of black inks for use in inkjet printers. A rather large literature exists that address similar questions for whites [2-5] which have been studied for 100 years. MacAdam assessed whiteness both visually and instrumentally [1] and there are numerous standards for the instrumental assessment of whiteness [6]. In comparison, the assessment of blackness has received relatively little attention. The aim of this work is to partly address this and to develop ideas towards a blackness index.

Black is a color, albeit one that in its purest form lacks chroma. Color results from human perception of the objective world so that various physical phenomena, physiological mechanisms and psychological effects combine to affect our perception of color. Color perception is generally regarded to have three dimensions; hue, value and chroma. Some work has been carried out to determine observers' preferences for color, especially those of different hue. As early as 1959, Guildford and Smith asked 20 observers to judge 316 differently colored samples from the Munsell Book of Color [7]. Guildford and Smith found that observers liked blues and greens and disliked yellows. They also found that observers preferred more saturated colors. The notion that people like blue and dislike yellow has been confirmed by much research over the last 50 years. Most recently, a study asked 48 observers to rate 32 colors from the Berkeley Color Project and confirmed that blue and greens were preferred and yellows were disliked [8]. Furthermore, in the 1990s, Saito carried out a cross-culture study about color preference of Koreans, Japanese and Taiwanese but revealed no significant cultural differences [9].

This study aims to explore blackness preference and blackness perception for blacks of different hue and for observers from different cultures. *Blackness preference* relates to whether observers prefer one black rather than another; *blackness perception* relates to whether observers consider one black sample to be more black than another. Whether these two terms are distinct will also be explored by the work.

Experimental

Methods

The set of stimuli was 13 colors (ten chromatic and three achromatic colors) taken from the Munsell system to represent blackish colors of varying hue at constant levels of value and saturation. The darkest color available in the Munsell system for each Munsell hue (R YR Y GY G BG B PB P RP) was used in addition to three neutral samples (one with the same value as the chromatic samples and the other two were lighter and darker). In the Munsell system, each color is represented by a hue, a value (denoted by V) and a chroma (denoted by C). Thus, V/C = 1/2 is a color with value 1 and chroma 2. The systematic color names and RGB values are shown in Table 1. The all RGB values are from 2006 WallkillColor Table of Munsell Conversion Program (*WallkillColor* Munsell Conversion Software).

The stimuli were presented to the observers on a computer screen GUI (written in MATLAB) on a neutral grey (R=G=B=133) background. The stimuli were each 8 cm × 8 cm and viewed from approximately 90 cm. The computer screen was calibrated but not characterized. This was a deliberate decision for this work because the errors that result from even carefully characterized screens would likely be greater than the small differences between the stimuli used. However, the CIE tristimulus values of each displayed stimulus were carefully measured using a Minolta CS100 colorimeter. This means that the colours of the displayed stimuli were known but not necessarily exactly the same as the Munsell samples the colours were derived from. The white of the display was used in subsequent calculations of CIELAB values for the stimuli.

The color samples were presented to the observers in pairs (see Figure 2). The experiment was carried out in two phases. First, the observers were asked to choose which color (of a pair) they prefer (we refer to this as *blackness preference*); second, they were asked to choose which color was the closest to a pure black (we denote this as *blackness perception*). Note that the two phases were not inter-leaved; rather, the observers judged all the pairs in phase 1 (blackness preference) and then, were presented with the pairs of color samples again and asked to judge according to phase 2 (blackness perception). All observers were tested in the same environment (CRT monitor at a distance of 90 cm, a visual field size of 15°, and using the same computer in a dark room). Observers were asked to indicate their choice by pressing the button below the color samples (see Figure 2) after which the next pair of color samples would be displayed.

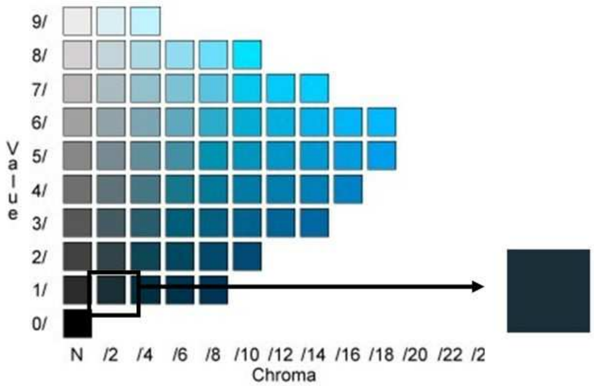

Figure 1: An example Munsell page showing the position of one of the samples used in the experiment with Value 1 and Chroma 2. The neutral samples (N0, N1 and N2) can also be seen.

Munsell Sample	RGB		Munsell Sample	RGB
N0	[0 0 0]		N1	[34 34 34]
N2	[52 52 52]		5B 1/2	[19 36 43]
5BG 1/2	[20 36 37]		5G 1/2	[24 36 31]
5GY 1/2	[31 35 24]		5P 1/2	[41 30 45]
5PB 1/2	[28 34 46]		5R 1/2	[48 28 32]
5RP 1/2	[45 28 40]		5Y 1/2	[40 33 16]
5YR 1/2	[47 30 23]			

Table 1: Munsell notations and visual representations of Munsell samples used in the experiment.

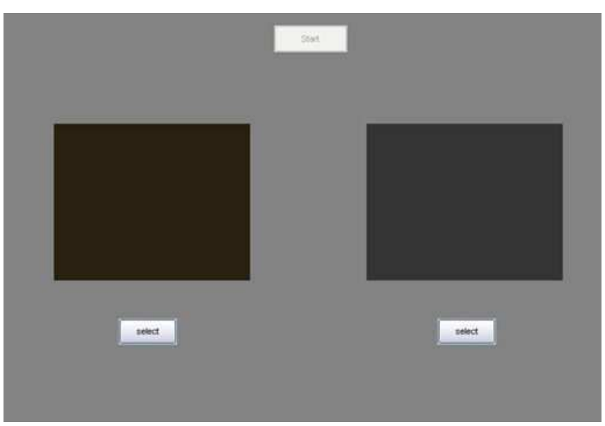

Figure 2: The GUI used in the experiment.

In this study 40 observers took part; 20 Chinese people and 20 UK people of whom 24 were female (13 Chinese and 11 UK) and 16 were male (7 Chinese and 9 UK). All of these observers passed the Ishihara Test for color blindness before participating in the experiment and were therefore assumed to have normal color vision.

Data analysis

In this study a complete pair-wise comparison procedure was used. That is, the stimuli were presented in pairs and the observer was forced to choose one of a pair over the other according to some criterion – phase 1 (blackness preference) or phase 2 (blackness perception). The term *complete* is used to indicate that every sample was compared with every other. Therefore for the 13 samples there were 78 paired comparisons meaning that there were 3120 (78 pairs × 40 observers) total observations for each of the two phases.

The paired-comparison technique is widely used in various types of study to investigate preferences, attitudes, voting systems, social choice, public choice and even multi-agent AI systems [10,11]. Paired-comparison techniques are particularly used in color psychophysical experiments. Thurstone showed that the technique can be used to order a set of items according to preference or importance and, crucially, according to an interval scale [12].

The comparison matrix was constructed for the stimuli S_i for i ∈ {1, 2, 3…13}. At the beginning of the experiment the entries of the comparison matrix are all set to zero. Each time an observer made a response the appropriate entry in the matrix is incremented by 1. For example, if the observer is viewing samples 1 and 2 and prefers sample 2 then the entry for S_2-S_1 is incremented. Once all observations have been made and the comparison matrix is complete, each entry in the comparison matrix is converted into a preference ratio by dividing by $(N\text{-}1)K$ since each sample was compared with each of the other N-1 samples by K observers. The preferences ratios are in the range 0-1. The preference ratios are converted to generate a corresponding table of units of standard normal deviates by calculating the inverse of the standard normal cumulative distribution (the *normsinv* function in Excel). The columns of the table are then averaged to generate estimates of the scale values [11].

Results

Blackness Perception

The experiment was conducted in two phases, to study blackness preference and blackness perception, as mentioned earlier. In this section the results of the blackness perception phase are analyzed. Recall that observers were asked which of two black samples they judged to be closest to a pure black.

Table 2 shows the CIE values of all color samples as measured by colorimeter which according to the white point in same screen. As can be seen in Figure 3 the ten chromatic colors are distributed around (and are almost equi-distance from) the reference white in CIELAB color space. (The samples are not uniformly distributed but this does not imply that CIELAB is not uniform; see the note earlier about the display being calibrated but not characterized.)

Sample	L*	a*	b*
N0	10.23	1.37	1.71
N1	32.89	0.68	2.62
N2	40.89	-1.34	2.69
5B	32.73	-4.43	-4.66
5BG	31.92	-7.93	-0.00
5G	32.51	-10.36	5.62
5GY	31.92	-6.65	11.42
5P	32.65	8.04	-6.22
5PB	32.83	-0.99	-6.32
5R	31.83	8.92	3.56
5RP	32.02	10.61	-2.98
5Y	32.24	-4.62	18.69
5YR	30.70	3.64	12.22

Table 2: CIELAB color coordinates as measured experimentally.

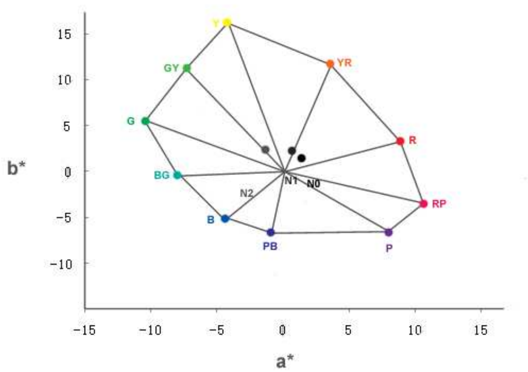

Figure 3: Distribution of color samples in CIELAB space.

Sample	Chinese	UK	Male	Female	All
N0	2.15	2.15	2.15	2.15	2.15
N1	0.80	0.96	0.94	0.83	0.85
N2	-0.49	-0.48	-0.54	-0.45	-0.48
5B	-0.22	-0.11	-0.08	-0.26	-0.17
5BG	-0.12	-0.14	-0.20	-0.08	-0.13
5G	-0.20	0.01	-0.01	-0.15	-0.10
5GY	-0.26	-0.18	-0.10	-0.31	-0.22
5P	-0.29	-0.41	-0.49	-0.27	-0.35
5PB	0.44	0.36	0.36	0.45	0.38
5R	-0.57	-0.61	-0.67	-0.52	-0.58
5RP	-0.47	-0.50	-0.57	-0.43	-0.48
5Y	-0.45	-0.61	-0.47	-0.56	-0.52
5YR	-0.37	-0.44	-0.35	-0.44	-0.40

Table 3: Scale values of color samples according to the 'pure black' criterion.

Table 3 shows the scale values of each color sample that results from five groupings of the observers (Chinese, UK, male, female, and all). The greater and more positive the scale values the more the sample was judged against the criterion of being pure black. Figure 4 illustrates the scale values of color samples. It shows that N0 has the highest scale value (2.15) of all the samples. This result indicates that people considered N0 to be the nearest color to pure black. This is expected, since N0 has no hue and is the darkest of all the samples being considered. Samples N1 and 5PB are in second and third places respectively. Samples N2, 5R, 5RP and 5Y were considered to be the least black of all the samples.

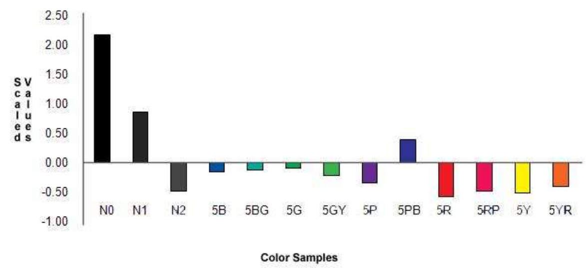

Figure 4: Scale values of color sample according to the 'pure black' criterion (results pooled over all observers)

Figure 5 shows the scale results according to nationality (China and UK) and indicates that there are little differences in blackness perception between the UK and China populations. Only 5G shows any substantial difference at all. UK observers ranked this to be the fourth blackest but Chinese observers did not rank this sample highly.

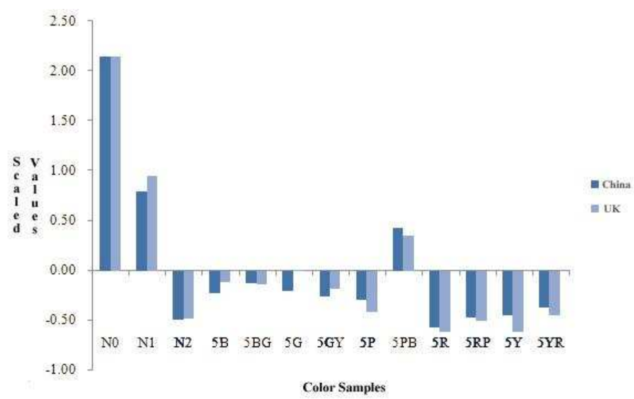

Figure 5: Scaled values of analysis of color samples closed to pure black by scaling according to nationality (UK and Chinese).

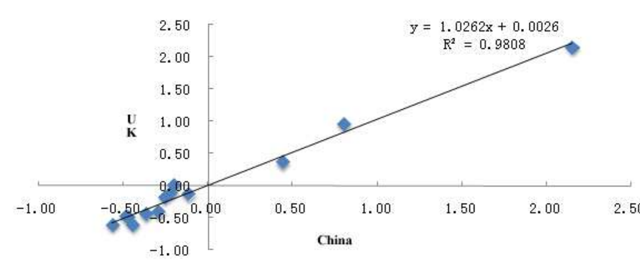

Figure 6: Correlation coefficient of analysis of color samples closed to pure black by scaling according to nationality (UK and Chinese).

Figure 7 allows a direct comparison between male and female observers (pooling data over both nationalities). Interestingly, although results from female and male observers are broadly correlated, there are some larger differences compared to when we considered the effect of nationality. Thus, irrespective of gender, samples N0, N1 and 5PB are considered to the three blackest samples; however, the correlation coefficient (r^2) is 0.96 (c.f. 0.98 for the nationality comparison). A closer examination of the results suggests that both male and female observers do not rate N2 and 5R as being very black (5R = -0.67, N2 = -0.54 for male; 5R = -0.52, N2 = -0.45 for female) (Figure 7). However, males give 5RP a low score as -0.57, but females think 5Y (5Y= -0.56) is not close to pure black. But in general, gender does not have a significant influence on blackness perception

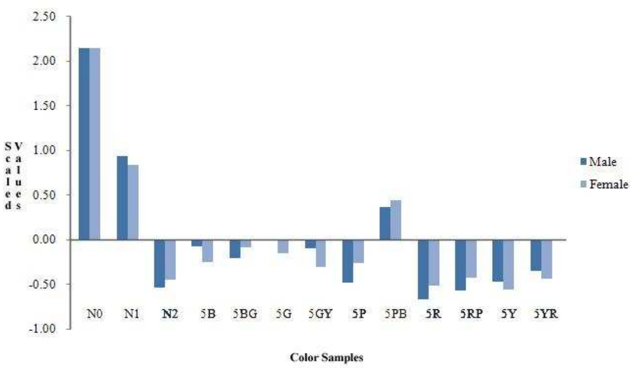

Figure 7: Scaled values for color samples closed to pure black by scaling according to gender (Male and Female).

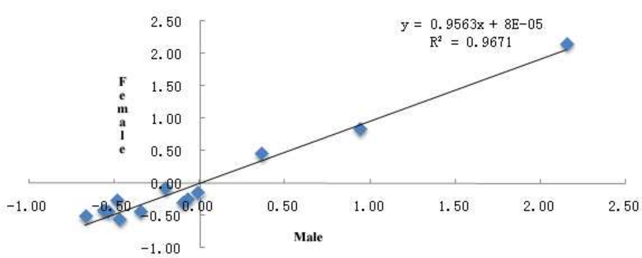

Figure 8: Correlation coefficient for color samples closed to pure black by scaling according to gender (Male and Female).

According to the results in this phase, Figures 6 and 8 (the correlation coefficient (r^2) is 0.98 for the nationality and 0.96 for the gender) indicate that neither culture nor gender have a significant influence on blackness perception. Regardless of cultural background, there is a common understanding of what is black.

Blackness Preference

The earlier part considered blackness perception of observers with particular emphasis on the effect of hue. The results indicated that there were almost no differences between UK and Chinese observers or between male and female observers. The results of phase 1 of the experiment (where observers were asked to indicate which of a pair of samples they preferred – note that they were asked this question first and that preference was not suggested in terms of blackness) will now be considered.

Table 4 displays the scores of colors according to the selection of color preference in each pair. It also shows by three groups: nationality, gender and all.

Sample	Chinese	UK	Male	Female	All
N0	0.12	-0.07	0.09	-0.01	0.03
N1	-0.05	0.06	0.07	-0.04	0.01
N2	-0.02	0.08	-0.13	0.14	0.03
5B	0.31	0.49	0.54	0.32	0.40
5BG	0.06	0.37	0.35	0.14	0.22
5G	-0.16	0.12	0.06	-0.06	-0.01
5GY	-0.39	-0.18	-0.03	-0.47	-0.28
5P	0.54	0.04	-0.12	0.57	0.28
5PB	0.38	0.48	0.65	0.31	0.42
5R	-0.21	-0.07	-0.34	-0.02	-0.13
5RP	0.61	0.10	-0.01	0.57	0.33
5Y	-0.70	-0.70	-0.59	-0.77	-0.68
5YR	-0.49	-0.69	-0.51	-0.66	-0.58

Table 4: Scaled values for color preference.

Figure 9 shows the scaled values for color preference. Samples 5B, 5PB and 5RP are the most preferred and samples 5GY, 5Y and 5YP are the least preferred. The data suggest that the most preferred samples have purplish/bluish tint and the least preferred samples have a yellowish tint.

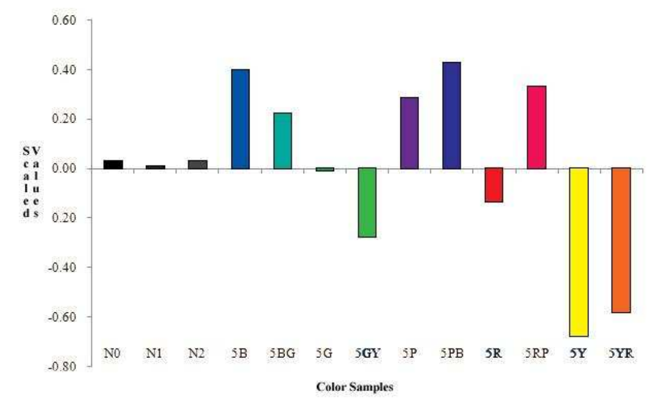

Figure 9: Scale values of color preference.

Figure 10 indicates the general order of preference of color samples in different nationality groups. As indicated in Figure 13, 5PB and 5B are commonly preferred in both groups and 5Y, 5GY and 5YR are disliked. Almost all people in these two groups preferred blue tone colors and disliked yellow tone. As Figure 11 shows, 5B, 5PB have a high preference score for both groups (5B = +0.37, 5PB = +0.48 for UK; 5B = +0.31, 5PB = +0.38 for Chinese). 5Y, 5GY and 5YR are the least preferred samples in both groups (5Y = -0.70, 5GY = -0.18 and 5YR = -0.69 for UK; 5Y = -0.70, 5GY= -0.39 and 5YR = -0.49 for Chinese). Compared with the UK observers, 5P (+0.54) and 5RP (+0.61) have high scores in the Chinese group and were ranked in first and second places. But 5B (+0.49) and 5PB (+0.48) was clearly the favorite colors for UK observers. Generally, there was more variance in the scale scores for the UK observers than for the Chinese observers.

Figure 12 indicates the differences between male and female responses. Both females and males like blue and purple tones. The colors which contain blue always have high scores, such as 5B, 5PB and 5BG. The results also show that females do not like yellowish color samples: 5Y, 5YR and 5GY are at the bottom of the scaling list. But almost all males also do not like reddish colors because the scores of 5R, 5YR are the lowest color samples: -0.34 for 5R and -0.51 for 5YR. Compared with males, the colors which contain purplish tint such as 5P (+0.57) and 5RP (+0.57) have a high scores in female group and were ranked in first and second places.

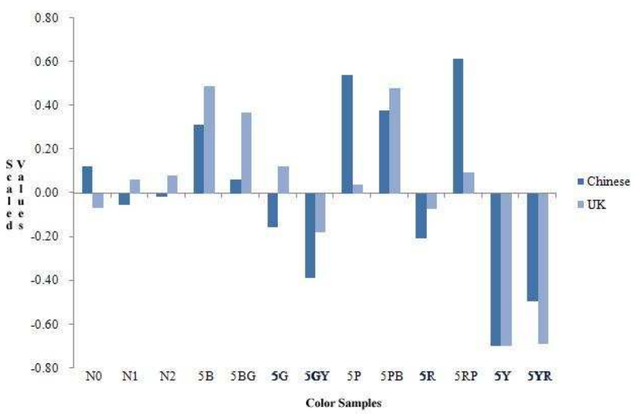

Figure 10: Scaled values for color preference scaling according to nationality (UK and Chinese).

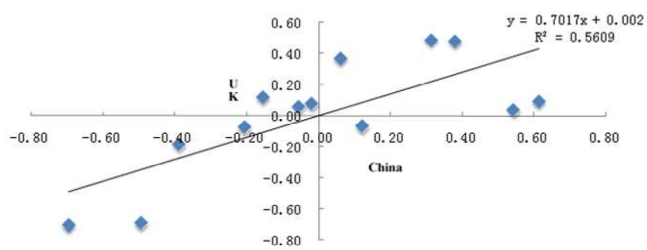

Figure 11: Correlation coefficient for color preference scaling according to nationality (UK and Chinese).

Figure 11 and Figure 13 could indicate that culture differences play an important role in color preferences. The correlation coefficients (r^2) for nationality and gender are 0.56 and 0.37 respectively. This could indicate that color preference is influenced by the culture, and that nationality has a greater effect on color preference than gender. However, the interpretation of correlation coefficients is not straight forward. The results could simply indicate that there was much more variability between observers for phase 1 than for phase 2.

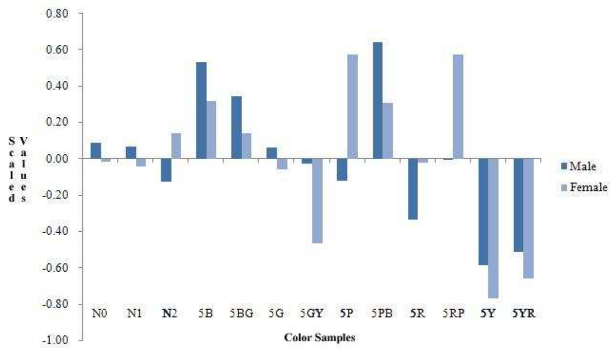

Figure 12: Scaled values for color preference according to gender (Male and Female).

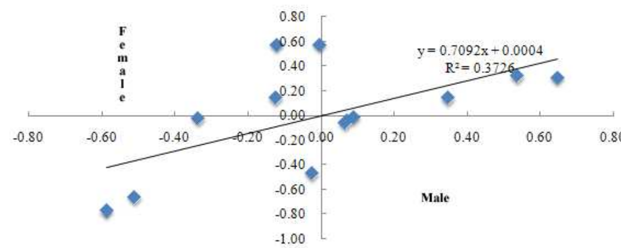

Figure 13: Correlation coefficient for color preference according to gender (Male and Female).

Conclusions

The main aim of this study was to investigate the relationship between blackness perception and blackness preference and to explore the effects of nationality and gender on this relationship. In this study particular emphasis was placed on hue.

When observers were asked about which black is a pure black neither nationality nor gender differences had a significant impact on results. For example, the scale values derived from observers from Chinese and UK observers were strongly correlated. The correlation coefficients (r^2) for the nationality and gender comparisons were 0.98 and 0.96 respectively.

When observers were asked about color preference, the results were very different. The correlation coefficient for the nationality comparison is 0.56 and for the gender comparison is 0.37. This could suggest that there are systematic differences between nationality and gender groups in this regard. On the other hand, Saito studied Korean, Japanese and Taiwanese nationalities and found that culture plays no significant role in more general color preference [9].

It is no surprise that sample N0 was considered the most black sample and was also the more preferred black since it was the darkest and least chromatic of the samples. However, the results for the stimuli that varied in hue (but had similar chroma and lightness) were interesting. Samples 5PB and 5B were preferred blacks compared to samples 5Y, 5GY and 5YR. In fact, although the blackness perception experiment revealed sample N0 to be the blackest sample, the blackness preference experiment revealed that several chromatic samples (notably 5PB and 5B, but also some others) were preferred to N1 and even N0. Therefore it would seem that observers have a strong preference for bluish blacks and a lesser preference for yellowish blacks. The use of paired-comparison (as opposed to other scaling techniques such as categorical judgement) means that only relative statements such as the preceding one can be made. However, the paired-comparison technique was preferred because it is very accurate and would maximize the possibility of detecting cultural differences that could be subtle.

The preference for bluish blacks is consistent with general studies on colour preference; for example, Hogg found that that blue and purple are the most preferred hues and yellow is the least preferred [13]; similar findings have been found by other researchers (e.g. [8]).

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