Effect of Black Background on Color Appearance of NCS Samples[1]

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Abstract

Three samples, differing only by one step in blackness *s* and/or chroma *c*, were selected from each of 24 hue pages in the NCS atlas. Skilled NCS staff members compared two of the samples on differing (black or gray) backgrounds and later made absolute judgments in NCS notation for the same samples. Comparison judgments of relative lightness were closely correlated with judgments of relative whiteness/blackness. Samples received lower *s* notations when viewed on black backgrounds than when viewed on gray. Mean *c* notations were also lower on black than on gray for most samples. But values of chroma (C) computed according to the Hunt 94 color appearance model are consistently *higher* on black than on gray proximal fields. Lightness (J) values computed by the same model indicate, as expected, that the model fails to give a satisfactory account of simultaneous contrast.

Introduction

Interactions of hue, lightness and chroma create problems for these concepts as they are defined by the CIE. With related colors the problems are complicated by the emergence of grayness when the surround has sufficient luminance. Pokorny, Shevell and Smith (1) discuss these problems and cite the work of Evans (2) in pointing out that "darkness can be induced by the presence of surrounds, and is interpreted as greyness."

The Swedish Natural Color System (NCS) makes explicit use of a whiteness-blackness dimension, and it distinguishes this dimension from lightness. Unlike the Munsell system, where Value is explicitly tied to the reflectance of a sample, NCS lightness is defined by a heterochromatic match between the sample and a gray scale, using a minimally distinct border criterion. Both dimensions are affected by the relative luminance of sample and background; are they in some sense independent dimensions, or are they perhaps different terms for the same dimension of color appearance?

If lightness and whiteness-blackness are really separate dimensions of color appearance, then working with observers accustomed to NCS concepts may be a good way to get evidence about their separateness. NCS notation is defined for samples viewed on a white background; putting samples on black or gray backgrounds will change their lightness, their whiteness-blackness (NCS *s*), and possibly also their chromatic content (NCS *c*). The research was designed to induce such changes and to study how they co-vary. It was also intended to provide quantitative evidence of the effect of background upon lightness and chroma, evidence that could then be compared with predictions of lightness (J) and chroma (C) calculated from the Hunt 94 color appearance model (3).

Method

Chromatic test samples were selected from 24 hue pages in the NCS atlas. Three samples were used from each page: a primary sample (P), the sample of the same chroma *c* but next lower blackness *s* (here called Ls), and the sample of next lower *s* and next higher *c* (Hc). A large rectangular array was placed on an easel inside a viewing booth under D65 illumination (1150 lux). The array had a 36-piece Mondrian border surrounding two 13.5° by 21° backgrounds, one black and one gray, and the 4° by 7° colored samples were placed in the center of either the black or the gray background (Figure 1).

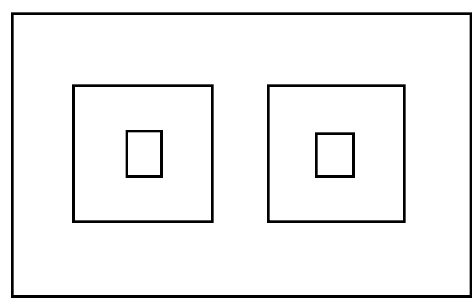

Figure 1

Three experienced staff members of the Scandinavian Color Institute in Stockholm served as observers; the experiment was conducted in their main office. During the first

[1] This research was carried out while the author was Visiting Scientist at the Swedish National Defense Research Establishment (FOA) in Linköping, Sweden. The cooperation and support of the study by both FOA and the Scandinavian Color Institute in Stockholm are gratefully acknowledged.

of two experimental sessions, the Os made comparison judgments of different samples, one on black and the other on gray, which had been selected in pilot studies as likely to appear similar to each other under these different background conditions. O reported whether the Ls (or Hc) sample on gray background appeared (1) lighter or darker, (2) more or less white (or black), and (3) more or less chromatic than the P sample on black background. The trial always began with a medium gray (4000 N) background on the right; when O reported some difference between the samples, the experimenter changed the background to a lighter or darker gray and asked O to judge the pair again. In this way a gray background was sometimes found which removed the difference in color appearance, and the two actually different samples appeared to "match." Each O compared every P sample (placed on black) at least once with its same-hue Ls sample as well as with its same-hue Hc sample (each placed on gray).

In the second experimental session (Absolute Judgment), only one chromatic sample was shown at a time, and it was placed either on the black or on the gray side of the display; a gray paper filled the sample area on the other side. For each sample presented, O gave a complete NCS description of the color appearance of the sample by stating the apparent *s*, *c*, and hue of the sample under these viewing conditions. Each O made 63 to 70 such judgments during the session.

Results and Discussion

Comparison Judgments: The black background did not consistently make the P sample appear either less or more chromatic than its same-hue Ls sample with the same *c* content, but it did decrease its blackness content and increase its lightness. The Ls sample, with *s* content lower by 10 NCS units than the P sample, was reported as equal or *blacker* than the P sample on 62.5% of the trials, and it was reported as equal or *darker* on 71% of the trials. Lightness judgments did not follow the blackness judgments perfectly, but the two were closely correlated; on the 64% of trials where neither lightness nor blackness matched, almost all (61%) were cases in which the lightness and blackness differences were in the same direction. In comparisons between a P sample and its same-hue Hc sample, this close association of lightness and blackness judgments was also observed.

These judgments provide only slight evidence that lightness and blackness may be independent dimensions. Out of 144 comparisons, 20% were cases in which the two samples were said to match on one of these dimensions but not on the other. Only 3% were cases in which the samples differed on both dimensions and in opposite directions.

Lightness and blackness judgments can be examined in relation to the actual luminance differences of the colored samples. When this is done, it is clear that the Ls and Hc samples, which were always on gray background and were compared with P samples of *lower* luminance on black background, needed to have at least 30% more luminance than P in order to appear lighter than P under these viewing conditions.

Absolute Judgments: All Os gave lower *s* judgments to samples on black backgrounds than to the same samples on gray, indicating (as expected) that samples appear to have *less blackness* when they are viewed on black. The gray background decreased *s* relatively little, as compared with the NCS notation for white background, and in some cases not at all. Mean *c* judgments were also lower on black than on gray for most samples. These differences are small, but their direction is consistent; a black background tends to reduce the chromaticness perceived in a sample. Hue judgments also deviated more from the standard NCS notation when the samples were viewed on black background.

When the two samples from all of the 22 pairs that "matched" in the Comparison Judgment session were judged separately, each on the same background on which the match had occurred, in most cases O did not assign the same absolute judgment to both members of the pair on all three dimensions. Hue judgments, when they differed, were as likely to differ in one direction as in the other. Differing *s* and *c* judgments, on the other hand, were more likely to be in the direction of lower *s* and lower *c* for the P sample viewed on black, even though the sample on black was always nominally *more* black and *equally* chromatic relative to its matching sample on gray.

Applying the Hunt 94 Model

Luo, Gao, and Scrivener (4) report magnitude estimations of hue, lightness, and colorfulness for 13 small (2°) test patches surrounded by 6° induction fields varying in hue and L*. The data obtained in their two simultaneous contrast experiments were not predicted well by the Hunt 94 color appearance model, and they concluded that further modifications of the model are required to take into account the simultaneous contrast effect.

The experiment reported here offers a different test of the model's predictions for simultaneous contrast effects. In 22 cases, an O was able to report that the P sample on black background appeared to *match* the Ls sample on a gray background, even though the two samples had different photometric and colorimetric properties. It is of some interest to examine whether the Hunt 94 model predicts nearly equal values of lightness (J) and chroma (C94) for these pairs.

Since the two samples were viewed in the same light within the same larger display, the predictions were calculated with the same reference white brightness (Q_w) for all samples. The background, which determines adapting luminances for all samples, was assumed to have the chromaticity of the NCS achromatic samples in the booth illumination (x = .3164, y = .3316) and a luminance factor of 20 (as recommended by Hunt for "natural scenes"). The immediate backgrounds (black or gray) of the NCS hue samples in this experiment were regarded as the "proximal fields" for these samples, and parameters for a modified reference white were calculated for each different black or gray level used, as well as for a standard "white" with luminance factor 90. Model predictions were then calculated by a C++ program for each set of samples on each relevant "proximal field."

Just as Luo *et al.* have already reported, use of p = -1 in computing the modified reference white is unsatisfactory; J values greater than 100 resulted in this experiment. With p = -0.5 the J values are within an appropriate range, and the difference between J values for the P and Ls samples on the standard white background has a reasonable size. As Figure 2 shows, the difference is close to 10 for most hues. Hue numbers in Figures 2-6 follow the NCS hue circle, starting with Y10R as hue 1 and continuing through R as 10, B as 20, and G as 30 to Y at 40.

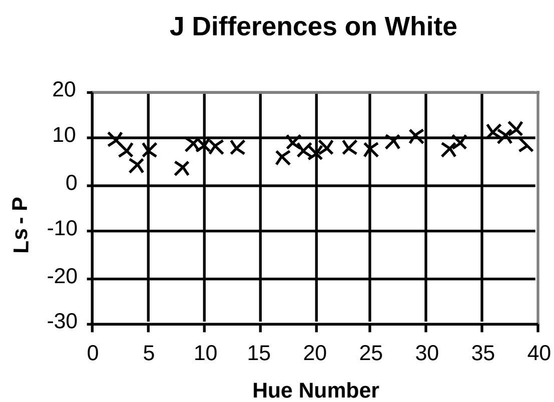

Figure 2

Figure 3 examines the difference in J values calculated for the conditions under which P and Ls pairs reportedly appeared matched. Some of these pairs show J differences close to 0, but many of them show negative differences greater than 10. Large negative differences represent cases in which the J value computed for P is greater than that computed for Ls, and these cases underscore the tendency for the Hunt model to *overestimate* the effect of the black background in "lightening" the test sample.

Ls and P samples had the same nominal *c*. Their C94 values calculated for a standard white background were also very similar; Figure 4 shows that the C94 differences between members of these pairs hover around 0. The C94 differences for Hc and P samples on the standard white ground are appropriately larger (Figure 5).

On the other hand, the C94 values calculated for P samples on black background are slightly but consistently *higher* than those calculated for the same samples on the standard white ground (Figure 6). This result is in conflict with the experimental finding that samples were judged less chromatic on black backgrounds than on gray (and less chromatic than their nominal *c* for white backgrounds).

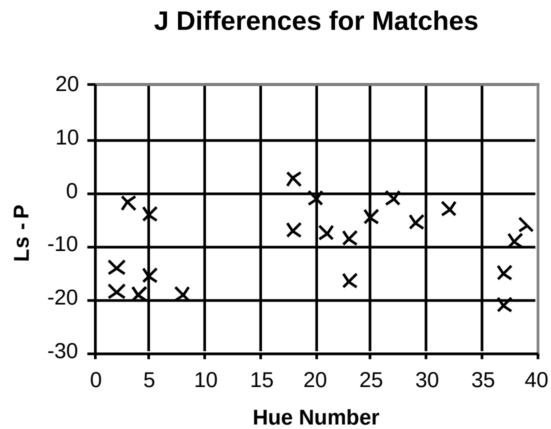

Figure 3

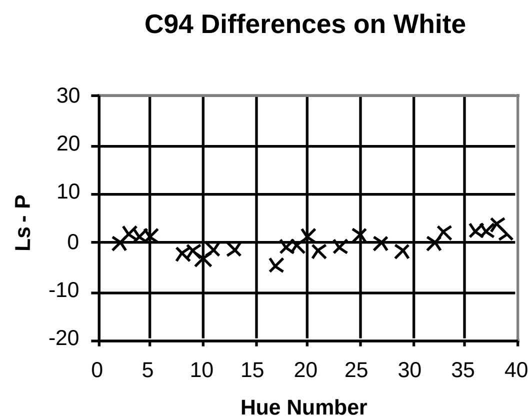

Figure 4

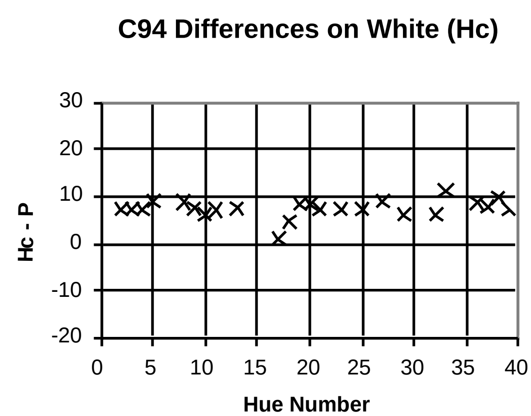

Figure 5

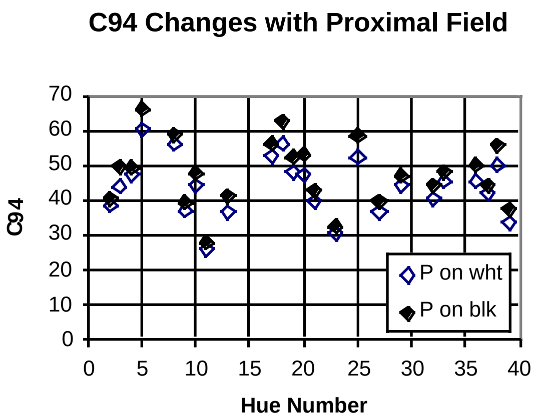

Figure 6

References

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2. R. M. Evans, *The Perception of Color*, Wiley, New York, 1974.
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