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Color and cesia: The interaction of light and color

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Abstract

Color and cesia are different aspects of the perception of light that contribute to the visual appearance of objects. This paper and the presentation at the Meeting are aimed at developing and explaining —through the methodic photographic recording of cases under study, visual comparisons and measurements— questions or phenomena produced by the interaction of color and cesia, dealing mainly with matte, glossy and transparent surfaces.

Introduction

Color and cesia are closely connected because of their relationship with light; both are different aspects of the perception of light that contribute to confer objects their visual appearance. Both phenomena interact expanding the countless number of different visual appearances that we are able to perceive. Color is the perception of the *spectral* distribution of light that produces a surface, or the perception of the spectral composition of a luminous source. For instance, a surface whose spectral curve is higher in the zone of long wavelenghts will be normally perceived reddish. Cesia is the perception of the *spatial* distribution of light, it is about how we perceive light that is reflected or transmitted by objects, either diffusely or regularly (Caivano 1991, 1994, 1996). For instance, a surface that reflects light in a diffuse way will be normally perceived matte, if it reflects light with a certain specular component it will be perceived glossy, if it transmits light diffusely it will be seen translucent, and if it does this in a regular way it will be seen transparent.

In both color and cesia the relationship between stimulus and sensation is not fixed but depends on three main factors —illumination, object and observer—, and is affected by other factors such as visual context, adaptation, contrast, etc. The classical variables of color are *hue*, *saturation* and *lightness* (or similar ones). The variables of cesia are the perceived degree of *permeability* to light, *diffusivity* of light, and level of *lightness* (which sometimes I have also called darkness, in the opposite sense). The dimension of lightness is shared by color and cesia, being the link that connect both phenomena.

Fridell Anter (1997) has characterized two classes of color presented by objects or surfaces: *inherent color* (the color that a surface has in the same conditions of illumination and observation by which the samples of a standard atlas used for comparison are in accordance with their notations), and *perceived color* (the color that we see in a specific situation, with any kind of illumination and under certain viewing conditions). It is possible to apply the same concepts to cesia: we can also recognize *inherent cesias* and *perceived cesias*. A clear transparent glass has an inherent cesia that we may characterize, for example, as: permeability P 95, diffusivity D 0, lightness L 95. But the same glass may be seen with different perceived cesias according to the conditions or illumination and observation; for instance, it will appear like a mirror when the illumination from the side of the observer is higher than from the opposite (see Caivano 1994: fig. 1).

Explaining some questions…

The present paper is aimed at developing and explaining some of the following questions or phenomena produced by the interaction of color and cesia:

1. Why a black glossy surface is perceived darker than a black matte surface? In general terms, why any color on a matte surface becomes darker if that surface is given a glossy finish?
   For a certain intensity of incident light, a matte surface produces a diffuse reflection, where the intensity of the reflected light is distributed approximately in the same amount for all angles, while a glossy surface concentrates the reflected light around the angle of reflection, and thus the light reflected in any other direction is relatively faint. Some reflected light is always seen from any direction in which a matte surface is observed (and for this reason it appears with some level of lightness), while if a glossy surface is observed from a non-specular direction, only a few light is reflected towards the observer, and thus it appears darker (see Fig. 1).
2. Why a glossy black surface can reflect a colorful scene with a higher degree of contrast and detail than a glossy white surface?
   In Fig. 2, the text of the image reflected on the black glossy sample can be clearly distinguished, while this does not happen on the white glossy sample. We can collect many cases and experiences that confirm this assert. The main explanation is that below the polished outer surface of the white glossy sample, the white pigment produces light scattering, which interferes with the sharpness of the reflected image. This does not happen with the black glossy sample, because below the outer polished surface, which reflects a good image, light is absorbed, and thus what we mainly see is the sharp reflection of the outer surface, even if it is dark in contrast.
3. How very glossy surfaces of different colors reflect a certain scene? How the color of the glossy surface affects the colors of the reflected scene? In what degree the colors of the reflected scene vary with every color of the glossy surface?
   Fig. 2 shows the case of two surfaces (a black and a white one) reflecting the same object. In the reflected scene, the colors of the object are strongly modified by the reflecting surface. Only black and white are shown in this paper for the sake of brevity and because of reproduction constraints, but the same arrangement, measurements and comparisons were made also for blue, red, green and yellow reflecting surfaces. In all cases, the colors of the original scene are strongly tinged by the inherent color of the glossy surface on which they are reflected. The comparisons are made in Fig. 3.
4. Why a chromatic color on a surface with a glossy finish becomes less saturated when the surface is given a matte finish?
   It is a well-known fact that the glossy edition of the Munsell atlas contains more samples than the matte edition, because the glossy samples reach a higher chroma. The reason is that the matte appearance is produced by diffuse reflection; light is scattered in all directions, and this produces a whitening of the surface color. Since the directions in which the light is reflected are manifold, at any part of the surface there will be some light reflected specularly towards the observer, and these points will look whitish. When whiteness increases, chromaticness decreases accordingly. Then, as compared to a glossy surface seen from a non-specular direction, the matte surface will look less chromatic or less saturated (Fig. 4), and also lighter, as we have seen in 1).

The following three questions cannot be fully developed here and will be addressed during the presentation:

5. What is the degree of variability of the perceived color on an opaque matte surface due to changes in illumination? If this color surface is glossy instead of matte, the degree of variability of the perceived color with changes in illumination will be higher or lower?
6. What is the degree of variability of the perceived color on an opaque matte surface due to changes in the angle of observation? If that surface is glossy instead of matte, the degree of variability of the perceived color with the changes in observation angle will be higher or lower?
7. What is the degree of variability of the perceived color on a transparent color surface in the same conditions as before? And what happens if it is a mirror? What color is a mirror? (a question already posted by Lozano 1985).

The development and verification of these questions is made by means of demonstrations through the methodic photographic recording of cases under study, and making measurements and visual comparisons.

In order to answer the first group of questions (mainly 2 and 3), an image containing white, black, gray and also some chromatic colors was placed in such a way as to be reflected by glossy acrylic surfaces having six different inherent colors (black, blue, red, green, yellow, white), all of them with the same degree of glossiness. These arrangements were photographed under the same lighting conditions and geometry, i.e., the pictures are identical except for the color of the glossy surface. Then, measurements were made of black, gray and white in the original image and in the reflected image upon the glossy surface (Fig. 2 shows only two examples). The glossy surface tinges with its own inherent color the reflected images in such a degree that the colors of the original image would not be recognized without the help of the context. The comparison and results show the great variety of colors that are the consequence of this (Fig. 3).

Applying the conclusions to environmental design

Aiming at establishing a connection with environmental color design, this paper intends to provide some concepts and methods to understand certain aspects of color in architecture and urban spaces, where the materials and surfaces may have many different colors and cesias interacting. Let me describe just one case. In a research being done by a group of students of architecture at Buenos Aires University, coordinated by Roberto Lombardi, the theme of urban color was faced in the following terms: What color is Buenos Aires city? (meaning how the city is generally perceived in the mind of the inhabitants). The usual answer by most people is that the city is gray. Now, the mentioned work consisted in taking pictures of sectors of the city with a certain methodology, and analyzing both the inherent and perceived colors, extracting the corresponding color palettes. The visible result is a great chromatic variety that would challenge this idea of the gray city. The chromatic variety is obviously more reduced for the inherent colors of the materials than for the perceived colors, where we can see an ample and diversified palette. My point is that this wide variety of perceived colors (even on a limited range of materials) is due to the interaction of color and cesia with the conditions of illumination, observation and context. In this paper we have typified and explained some of these cases.

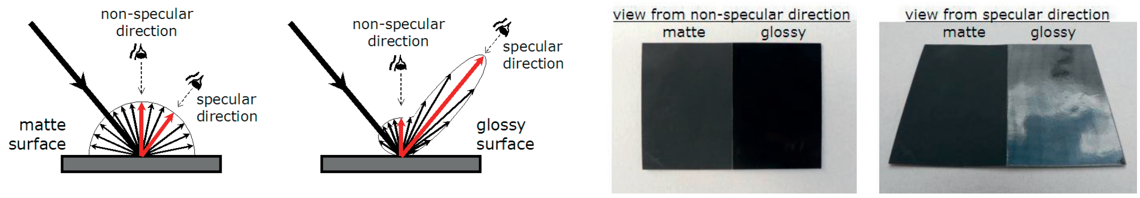

Figure 1. The matte surface shows approximately the same lightness for all angles of viewing. The glossy surface looks darker when seen from a non-specular direction, and appears lighter when seen from a specular direction (because it is reflecting the light source).

Figure 2. Black and white glossy surfaces reflect the AIC 2011 card (with black, white and chromatic colors) and the gray background. Above, the zones where black, gray and white are reflected in each case are extracted and measured.

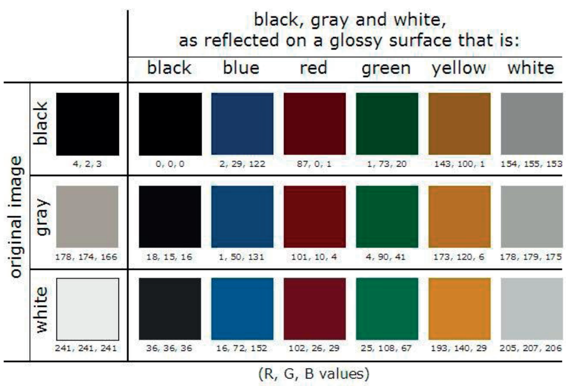

Figure 3. Comparison of colors white, gray, and black in the original image, as they are reflected on the glossy acrylic surfaces of different colors.

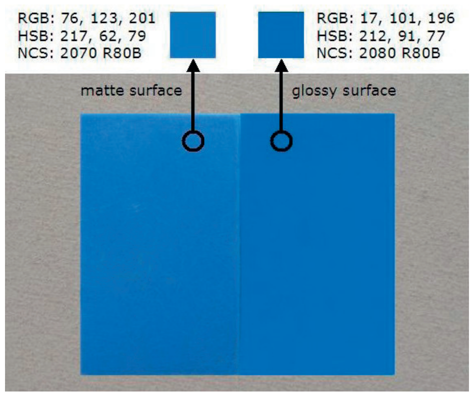

Figure 4. Two samples of the same material; the right one was left glossy, the left one was given a matte finish. It looks lighter and less saturated.

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