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Appearance

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Synonyms

Color appearance; Perceptual appearance; Total appearance; Visual appearance

Definition

Visual appearance refers to how things look to observers. Objects have physical properties, and in this regard, optical properties are usually most relevant together with size, texture, shape, etc. But what finally matters for vision is the appearance that objects have for an observer (human observers will be mainly referred to in this article; however, this is not restrictive to human beings since there are many other living species that have similar visual processing systems). The American Society for Testing and Materials (ASTM) as well as the International Commission on Illumination (CIE) define appearance as the aspect of visual experience by which objects are recognized [1, 2]. The ASTM specifies, furthermore, the definition of appearance from a psychophysical point of view: "perception in which the spectral and geometric aspects of a visual stimulus are integrated with its illuminating and viewing environment." The physical properties have, of course, influence on the way things look, but also the neurophysiology and psychology of vision play a very important role in determining how objects and the world appear to humans. Thus, it is important to understand visual appearance not merely in regard to physical aspects but as a sensation produced by the visual system when processing stimuli channeled by means of light – visible radiation. Visual appearance, understood as a visual sensation, i.e., what humans see, has certain attributes, which are also visual sensations. These include color, visual texture, gloss, and transparency. In the ASTM definition the "spectral aspects" refer, of course, to color, and the remaining aspects (including the perceived shape, size, etc. of objects) are usually considered as "geometric aspects." From these visual sensations observers get information about the environment and build their knowledge of the external world, which allows them to interact with the environment and with other individuals.

Historical Review of Studies on Visual Appearance

Under the heading of visual appearance a number of aspects are included such as color, texture,

R. Shamey (ed.), *Encyclopedia of Color Science and Technology*,
https://doi.org/10.1007/978-3-642-27851-8_225-2

gloss, transparency, and also the shape and size of perceived objects or stimuli. The psychologist David Katz was probably the first to understand the various kinds of phenomena that always accompany the perception of color [3]. He describes different modes of color appearance: surface color, film color, volume color, specular colors, transparent colors, perception of luster, etc. By the middle of the twentieth century, Arthur Pope realized that, in order to define a color with accuracy, i.e., giving account for different modes in which a color may appear, more than the three usual variables (hue, lightness, and saturation) are needed [4 , p. 28].

In 1953, the Committee on Colorimetry of the Optical Society of America published a book in which visual perception is classified into 11 "attributes of modes of appearance" [5]:

1. Brightness (or lightness)
2. Hue
3. Saturation
4. Size
5. Shape
6. Location
7. Flicker
8. Sparkle
9. Transparency
10. Glossiness
11. Luster

Lightness, hue, and saturation (attributes 1, 2, and 3) are the usual variables by which color sensations are described. Size, shape, and location (attributes 4, 5, and 6) are spatial categories of visual perception, which can be included in the category of spatial form. Flicker and sparkle (attributes 7 and 8) involve temporal variations in the perception of light. Finally, transparency, glossiness, and luster (attributes 9, 10, and 11) refer to the perception of different spatial distributions of light, aspects that will be included in the category of "cesia" to be described in the next section.

Richard Hunter proposed a classification of the geometric attributes of visual appearance [6]. He defined six different types of gloss and developed instruments for the measurement of some of these phenomena: goniophotometers, diffuse-reflection and specular-reflection meters, glossmeters, diffuse- and specular-transmission meters, etc. Before Hunter, August H. Pfund had already described an instrument for measuring gloss [7]. The American Society for Testing and Materials has standardized the measurement of various physical aspects related to visual appearance [8–11] and published a glossary of standard terminology [1].

Robert Hunt has developed a hypothesis for the measurement of color appearance under different conditions of illumination and observation, taking color as the central point of his study [12]. Sven Hesselgren observed that visual sensations, such as luster, reflection, and gloss, are not perceived as belonging to the color of an object but as something separate from color [13]. Ralph Evans, like Pope, also realized that the three variables normally used to define color are not enough to characterize color under different modes of appearance [14]. Evans concluded that it would be necessary to define at least five variables. In these conceptions, the phenomena of appearance have always been considered as aspects that accompany color sensations.

Other researchers have studied, either partially or globally, the aspects of visual appearance related to the different modes of distribution of light in space. Fabio Metelli tackled the problem of transparency from a phenomenological point of view, establishing a clear difference between physical and perceived transparency and developing a model that predicts the conditions under which the perception of achromatic transparency is possible [15]. Osvaldo Da Pos, following Metelli, enlarged the model to study the perception of chromatic transparency [16].

John Hutchings studied the phenomenon of translucency and its importance for the visual qualities of food. In articles published in 1993 and 1995 he integrated all the aspects into a model of total appearance [17, 18]. However, this model is mainly oriented toward the analysis of food [19] and for this reason includes also nonvisual aspects of appearance such as smell, taste (flavor), and also texture as felt in the mouth, in addition to visual texture. Paul

Green-Armytage proposed a three-dimensional model to organize what he called "qualities of surfaces" [20, 21]. Subsequently he introduced the term "tincture," borrowed from heraldry, to encompass color, texture, and cesia [22]. Robert Sève tackled the specific problem of gloss [23]. Michael Brill used the model of Metelli to formulate a series of rules for the perception of chromatic translucency [24].

In 2006, a technical committee of the CIE (Commission Internationale de l'Eclairage, International Commission on Illumination) published a report to set a framework for the measurement of visual appearance [2].

A Classification of Visual Appearance into Four Categories

It is possible to analyze a given scene and try to understand how most humans separate and categorize (by means of concepts and words) the main visual aspects involved. If the features shown in Fig. 1a are selected, people would agree on saying that they are different colors. If other features are selected, such as those shown in Fig. 1b, people will call them shapes (spatial forms). If the features selected in Fig. 1c are shown, people would call them textures. Finally, for the features selected in Fig. 1d the term cesia has been proposed.

Color can be defined as the aspect of visual appearance that results from the perception of different spectral compositions of light; it is what people are referring to when they say that some object or light stimulus is red, green, yellow, blue, black, white, gray, etc.

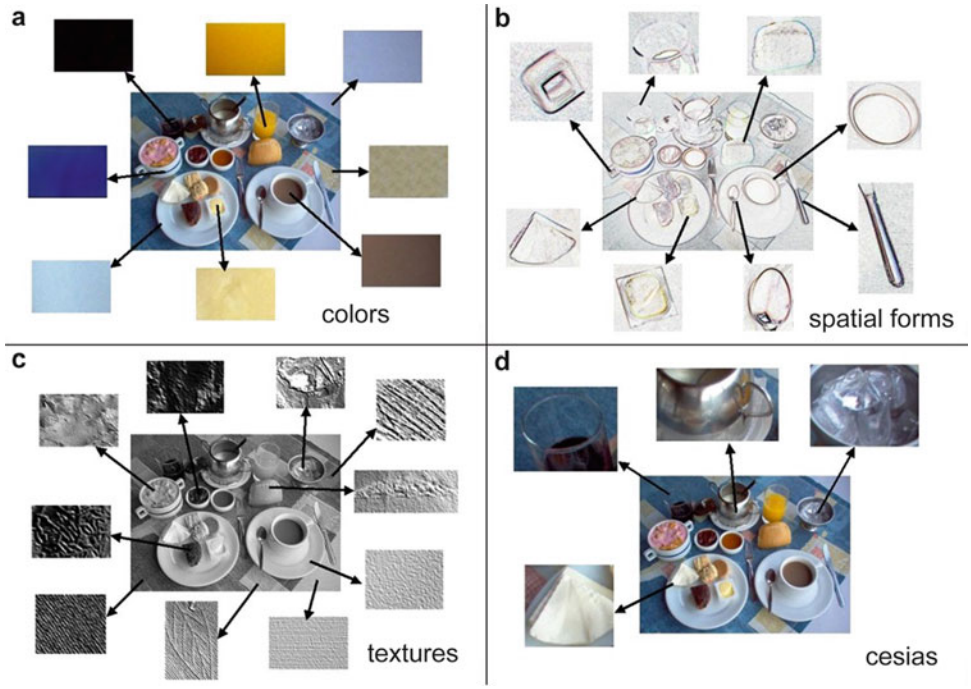
Spatial forms, or shapes, are built in consciousness from the perception of borders and their integration, so that they enclose or delimitate a portion of space. Spatial forms can be one dimensional (a straight line, a curved line, an irregular line, etc., which separate one portion of space from another), two dimensional (a triangle, square, circle, irregular surfaces, etc.), or three dimensional (a cube, a prism, a pyramid, a tetrahedron, a sphere, irregular volumes, etc.). They can have different shapes (as usually defined by the previous names), but they can also differ in size (length, surface, and volume) and proportion (defined by the relationships among the dimensions of the shape: length, width, and height).

Visual textures arise from the perception of sets of small elements that appear repeated in a surface or volume. The category of texture applies when these elements have no individual significance and are interpreted as making a whole, building a pattern that can be more or less regular or irregular. Visual textures can be distinguished and described by different variables or dimensions. These variables include density (the elements of the texture can be sparse, dense, or intermediate), predominant directionality (the elements can vary in direction or have no predominant directionality), and, of course, the shape and size of the relatively small elements whose repetition composes the texture. Visually perceived textures may be two dimensional (without relief) or three dimensional (with relief), the latter being also perceived by touch [25].

Beyond color, spatial forms, and textures, there are some other visual appearances that depend on the way in which differences in the spatial distribution of light are perceived. It is these spatial distributions of light that cause things to be seen as transparent or opaque, glossy or matte, or with intermediate appearances between these. Since there has not been a single global name or category to refer to these aspects, the neologism *cesia* has been coined for them.

Cesia

"Cesia" is a term invented around 1980 by César Jannello, to designate the perceptions resulting from the different spatial distributions of light. This concept was developed mainly by Caivano [26–29]. Cesia encompasses all the visual sensations from transparency to translucency, matte opacity to mirror-like appearance (passing through glossy appearance), and lightness to darkness. Cesias are related to color in the sense that both are different aspects of the perception of light, and color deals also with lightness and darkness. But there are aspects that cannot be

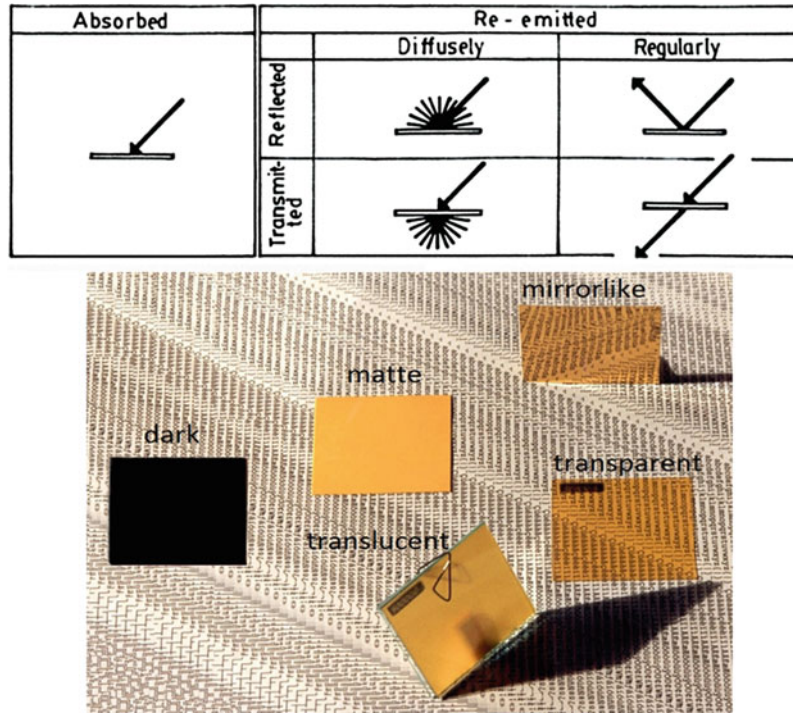


Appearance, Fig. 1 The same scene with different visual features selected and categorized: (**a**) Different *colors*. (**b**) Different *spatial forms* or shapes that appear defined by their borders. (**c**) If attention is paid to certain regularities or repetition of elements on the objects, the notion of *texture* can be applied. (**d**) Other visual characteristics such as the transparency of the glass, the white matte opacity of the paper towel, the metallic luster of the sugar pot, the glossy and semitransparent aspect of the ice cubes, and other similar ones have been given the term *cesia*

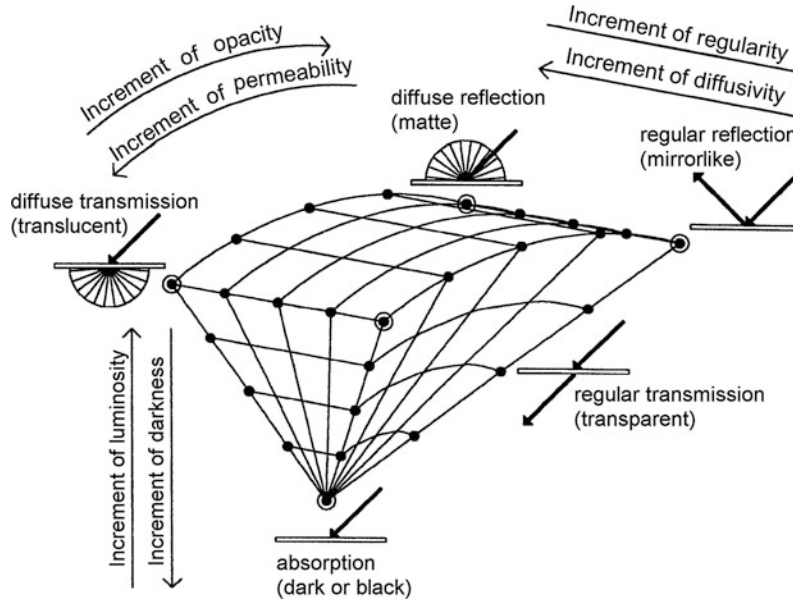
described by the three classical color dimensions of hue, lightness, and saturation. In this sense, cesia constitutes a category that can be added to the categories of color, visual texture, and spatial form in order to extend the possibilities of describing and classifying visual appearance. Three dimensions or variables can define cesia with respect to the perception of how light interacts with objects: permeability (from opaque to transparent), diffusivity (from regular to diffuse), and darkness (from light to dark). Light can be reflected or transmitted by objects, either diffusely or regularly, and it is the perception of these phenomena that is covered by the term "cesia." For instance, a surface that reflects light in a diffuse way will normally be perceived to be matte. If a surface reflects light with a certain specular component it will be perceived as glossy or mirror like. If it transmits light diffusely it will be seen as translucent, and if it transmits light in a regular way it will be seen as transparent. Finally, a surface that absorbs most of the light will appear dark or black (Fig. 2).

A three-dimensional model has been proposed to organize the three variables of cesia (permeability, diffusivity, and darkness). The model is a kind of inverted pyramid, with four vertices on the top for the sensations of matte appearance, mirror-like appearance, translucency, and transparency. The connections among these form scales with a variation of permeability (or the opposite, opacity) in one direction and scales with a variation of diffusivity (or the opposite, regularity) in a perpendicular direction. From any of these points, scales going down in lightness (or increasing darkness) connect to the point that is the place for black (Fig. 3).

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,



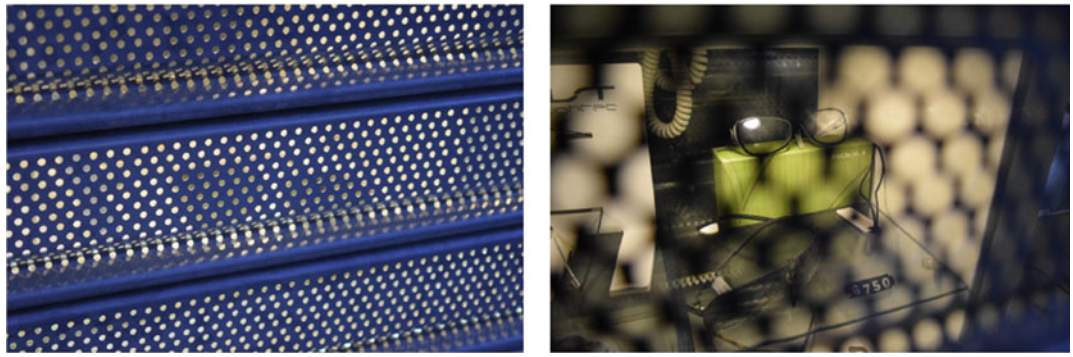
Appearance, Fig. 2 Cesia: processes followed by light falling on objects, and the way these stimuli are usually perceived



Appearance, Fig. 3 The three-dimensional model of cesias

contrast, etc. Some of these factors have been studied and exemplified with photographs by María P. Giglio [30]. To mention just an example: depending on the distance taken by the observer, an element can be perceived as more opaque or transparent, even when the physical arrangements of objects do not change (Fig. 4).

Color and cesia are closely connected because of their relationship with light; both are different aspects of the perception of light that contribute to



Appearance, Fig. 4 A screened shutter that covers a shop window goes from near opacity to near transparency. When the observer is at a certain distance, the surface of the shutter looks more opaque than transparent and objects behind it cannot be seen. When the observer gets closer, the small holes of the shutter tend to disappear, and the effect of transparency increases. (Photograph: M. Giglio)

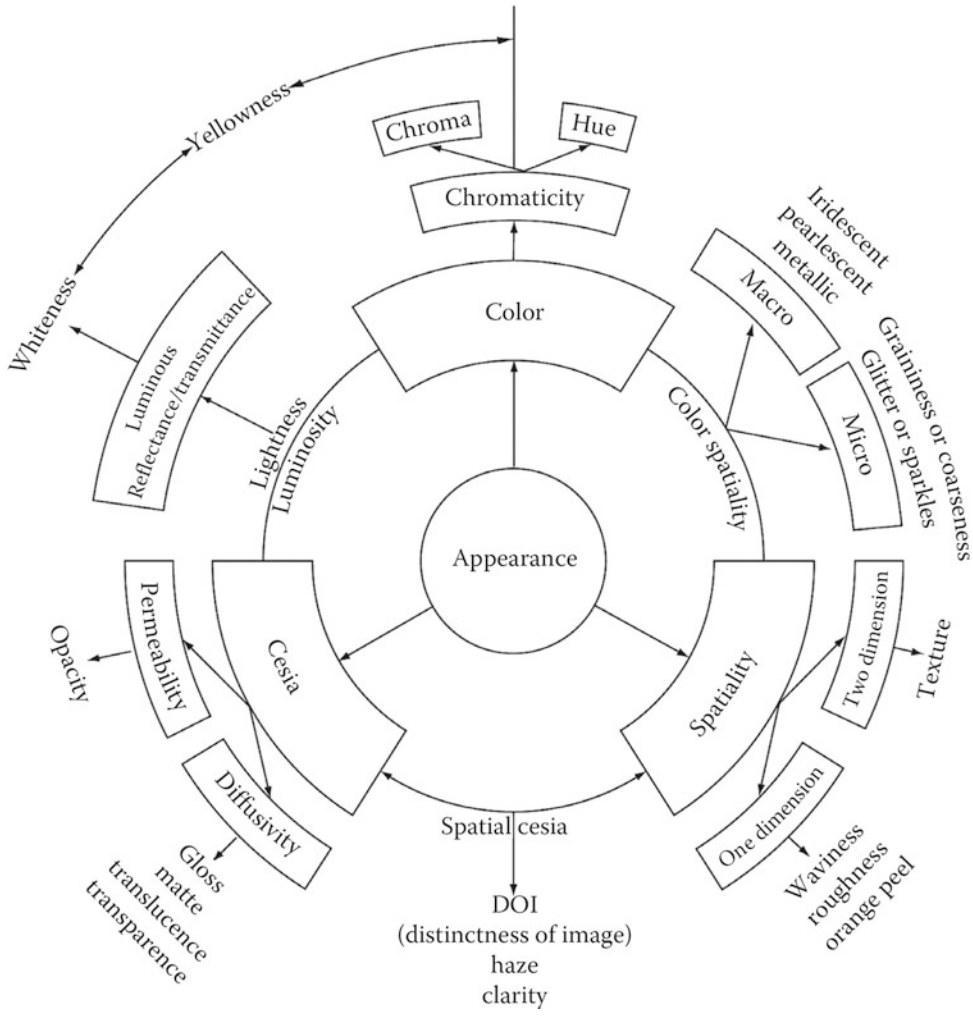
the visual appearance of objects. The dimension of lightness/darkness is shared by color and cesia, being the link that connects both phenomena. Color and cesia interact thereby expanding the countless number of different visual appearances that humans are able to perceive. When Ludwig Wittgenstein, in his *Remarks on Color* [31], is concerned with the different types of white, yellow and golden, gray and silver, "black" mirrors, etc. and when he says, "Opaqueness is not a property of the white color; any more than transparency is a property of the green," he is dealing, in reality, with this aspect that we call cesia.

Models to Organize Different Aspects of Visual Appearance

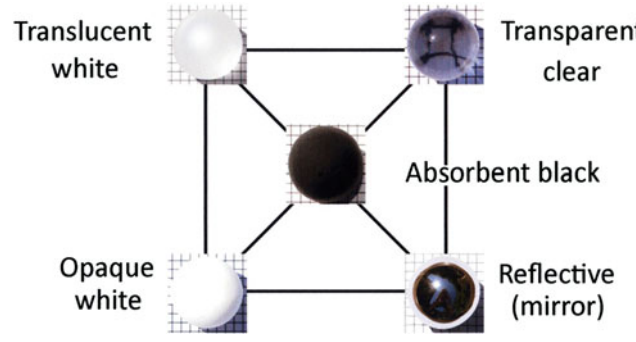
Roberto Daniel Lozano, one of the members of the CIE technical committee 1-65, proposed a new approach to appearance characterization, with a model that classifies visual appearance according to three main categories (color, cesia, and spatiality), which in turn includes subcategories and shows the interrelations and intermediate aspects among them (Fig. 5) [32].

More recently, Paul Green-Armytage proposed a model to link different modes and different aspects of appearance [33, 34]. The model shows relationships between the surface, volume, and illuminant modes of appearance as well as transparency, translucency, opacity, texture, gloss, metallic luster, and luminosity. Caivano identifies the five vertices of his inverted pyramid model of cesia (Fig. 3) as "primary sensations" [27]. These are opaque white, translucent white, transparent clear, mirror like, and black. Caivano's three-dimensional inverted pyramid can be presented in two dimensions (Fig. 6).

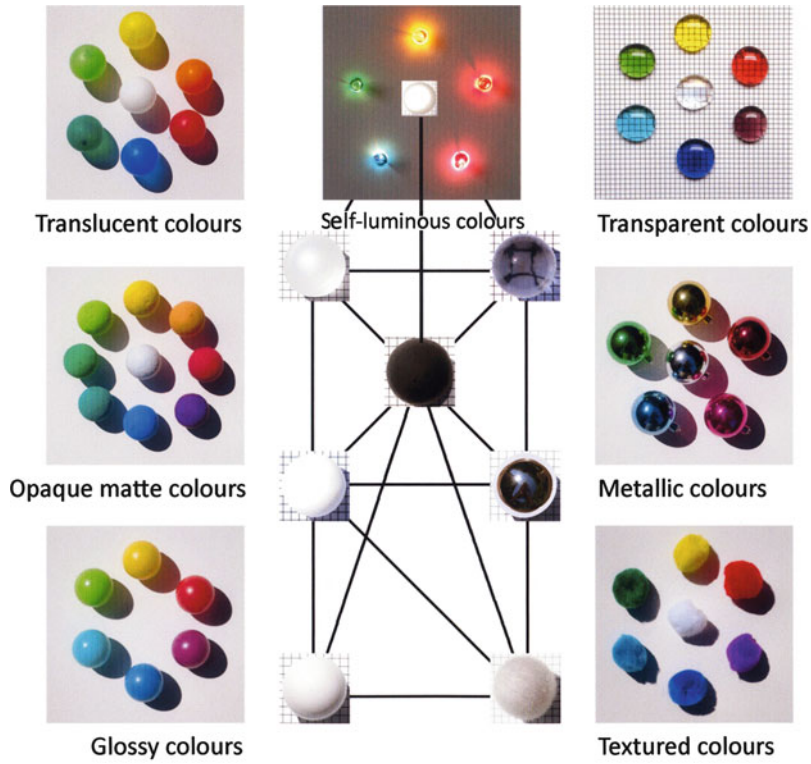
This two-dimensional representation of Caivano's model is at the center of Green-Armytage's model. Green-Armytage makes a distinction between gloss and metallic luster (mirror like), noting that scales can be constructed from a matte surface to surfaces that are increasingly glossy in one direction and from a matte surface to surfaces with increasing metallic luster in another direction. He also notes that scales can be constructed with increasing texture from three different starting points: smooth matte, smooth gloss, and smooth metallic luster. Matte, glossy, textured, and metallic aspects of appearance are all characteristics of the surface mode of appearance. The volume mode can vary between clear (transparent) and cloudy (translucent). In the illuminant mode light sources can appear in varying degrees of brightness with a notional maximum that can be described as glare. To Caivano's five primary sensations Green-Armytage adds three more: gloss white, textured white, and white light glare. Each of the seven other primary sensations can be connected with scales to black, and these scales can, in turn, serve as the achromatic axes of order systems for colors that are opaque,



Appearance, Fig. 5 The classification of visual appearance proposed by Lozano. (Reproduced with permission of R. D. Lozano)



Appearance, Fig. 6 Two-dimensional representation of Caivano's inverted pyramid model of cesia



Appearance, Fig. 7 Hue sequences in different aspects of appearance linked to Green-Armytage's model

translucent, transparent, and metallic (mirror like), as well as glossy, textured, and self-luminous. Green-Armytage's model, with color circles to correspond with the different primary sensations, is shown in Fig. 7.

Increasing apparent intensities of illumination can be represented on lines which converge at white light glare. The coherence of a light source, which affects appearances, can also be represented on the diagram. "Hard" light, as from direct sunlight and under which objects cast clearly defined shadows, is represented on the line connecting transparent clear to white light glare, and "soft" light, as from a heavily overcast sky and under which no shadows are cast, is represented on the line connecting translucent white to white light glare.

The various models described here can go some way to increasing awareness of the different aspects of appearance, and how they can be related, but no model can encompass the full experience of seeing the world in space and time.

Cross-References

- ▶ Gloss Meter
- ▶ Goniophotometer
- ▶ Katz, David
- ▶ Tincture
- ▶ Transparency

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