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Appearance (Cesia): Variables, Scales, Solid

The name cesia has been proposed for that aspect of appearance which deals with the sensations aroused by differences in the spatial distribution of light. A system for cesias has been developed contemplating: (1) a set of five primary sensations: transparence, specular reflection, translucence, diffuse reflection, and absorption; (2) a coordinate set of three variables or dimensions (permeability, absorption, diffusivity) by which any sensation of cesia can be specified or defined; (3) a notation system by which numerical values are assigned to each dimension, these numbers representing not physical measurements of stimuli but percentages of primary sensations as perceived; (4) a three-dimensional model for the organization of sensations. Recently, scales of cesia have been developed with the aid of rotatory disks holding sectors of materials producing the stimuli for the five primary sensations.

Le nom césie a été proposé pour désigner l'aspect de l'apparence qui traite des sensations provoquées par les différences dans la distribution spatiale de la lumière. Il a été développé un système de césies qui comporte: (1) un ensemble de cinq sensations primaires: transparence, réflexion spéculaire, translucidité, réflexion diffuse et absorption; (2) un groupe coordonné de trois variables ou dimensions (perméabilité, absorption, diffusivité), au moyen duquel on peut déterminer ou définir n'importe quelle sensation de césie; (3) un système de notation au moyen duquel on assigne des valeurs numériques à chaque dimension, représentant non pas des mesurages physiques des stimuli, mais des pourcentages des sensations primaires, telles qu'elles sont perçues; (4) un modèle tridimensionnel pour l'organisation des sensations. Dernièrement on a développé des échelles de césie, avec l'aide de disques tournants formés par des secteurs de matériels qui produisent les stimuli pour les cinq sensations primaires.

Der Ausdruck Cesia wurde vorgeschlagen, um jenen Gesichtspunkt der Erscheinungswesen zu benennen, die die Unterschiede der Beleuchtungswahrnehmung im Raum behandelt. Ein Cesiasystem wurde folgendermaßen entwickelt: (1) Eine Gruppe von Primärsinneseindrücken: Durchsichtigkeit, Rückstrahlung, Durchscheinen, diffusse Rückstrahlung und Absorption; (2) eine koordinierte Gruppe von drei Variablen oder Dimensionen (Durchlässigkeit, Absorption, Diffusionsvermögen), durch welche jedes Cesia bezeichnet oder genau beschrieben werden kann; (3) ein Bezeichnungssystem mit dem jeder Dimension Zahlenwerte zugeordnet werden können, welche nicht physikalische Messungen der Reize darstellen, sondern Prozentsätze der primären Sinneseindrücke, so wie sie wahrgenommen werden; (4) ein dreidimensionales Muster des Aufbaus der Sinneseindrücke. Kürzlich wurden mit Hilfe von rotierenden Sektorscheiben (welche die Stimuli für die fünf primären Sinneseindrücke erzeugen) Skalen des Cesias festgesetzt.

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1. Introduction

The term *appearance* alludes, in a broad sense, to a whole series of visual aspects in which color, texture, glossiness, translucence, transparence, and even sometimes shape and size of objects are included. In this context, color is usually defined as the aspect of appearance which results from differences in the *spectral distribution* of light, that aspect to which we refer by saying that something is red, green, blue, yellow, white, black, or any other tone. Beyond this, there exists a whole field which refers to those conditions producing differences in the *spatial distribution* of light, causing something to be seen as transparent, translucent, specular, glossy, matte, etc.

For these visual sensations there is not yet a generic term having broad acceptance. HUNTER refers to these aspects as *geometric attributes of appearance*, also including texture under this heading [1]; GREEN-ARMYTAGE discriminates these aspects from texture and labels them as *quality of surfaces* [2]; JANNELLO coined the term *cesia* [3], which also excludes texture and which I sustain in the proposal of an order system. This aspect of appearance is independent of color, though related with it [4].

Cesia, like color, is not an intrinsic property or attribute of materials and surfaces. The physical properties of a material (as regards transmission, absorption, reflection, and scattering of light), the conditions of illumination (intensity and direction of light), and the angle of seeing on the part of the observer, all contribute to the production of a certain sensation of cesia. The same object can appear having different cesias depending on the alteration of one or various of the above mentioned factors. For instance, a piece of glass looks transparent if it is observed perpendicularly to its surface, and behaves like a mirror when looked at from an angle whose deviation from the perpendicular is about 90 degrees.

2. Primary cesias

There are five sensations which are considered as primary cesias: transparence, specular reflection, translucence, diffuse reflection, and absorption. The following ideal standards are taken as the stimuli that make up these five primary sensations:

Transparence: a perfect transmitting material with 100% regular transmittance. Air meets the conditions for such an ideal [5; 6].

Specular reflection: a perfect mirror with 100% regular reflection. A surface of aluminium evaporated onto glass is the standard more closely approaching this ideal [5].

Translucence: a perfect diffuse and totally transmitting material with 100% diffuse transmittance. Such a material would be one that: (a) placed at the open top of a black velvet-lined box and illuminated from outside looks black (this means that it permits light to pass through towards the interior of the box without producing any reflection at its surface); and (b) placed against a spotlight and seen from the other side looks as a uniform white surface (this means that it permits light to pass through but it scatters light in its totality).

Diffuse reflection: a perfect matte white with 100% diffuse reflectance. A surface of pure barium sulphate powder approaches this ideal [5; 7].

Absorption: a perfect black with 100% absorbance. The device that produces a stimulus approaching this ideal is a black velvet-lined box with only a small aperture to look inside [8].

3. Variables and notation for cesias

When light falls upon an object, it may be (a) absorbed or re-emitted. The re-emitted portion may be (b) reflected or transmitted, and each of these transfers may occur in (c) a diffuse or regular way. The three perceptual variables or dimensions of cesia relate these processes:

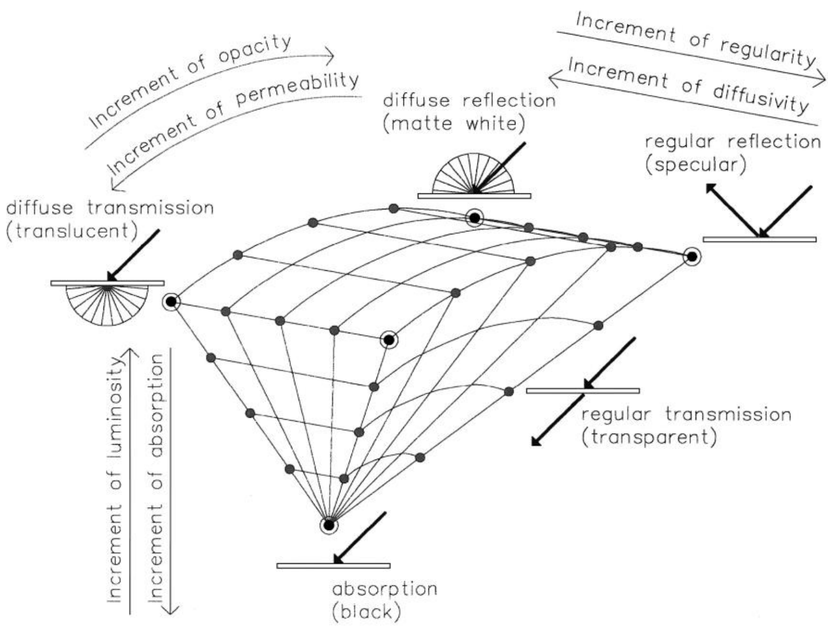

Fig. 1: Solid of cesias with the five primary sensations and the three kinds of variables. The eight scales developed are placed along the eight edges.

Absorption refers to the proportion between the subjective quantities of light seen to be absorbed and re-emitted. The pair absorption/luminosity forms the two sides of the coin in this variable.

Permeability refers to the proportion between the subjective quantities of light seen by transmission and reflection. The pair permeability/opacity constitutes the poles of this variable.

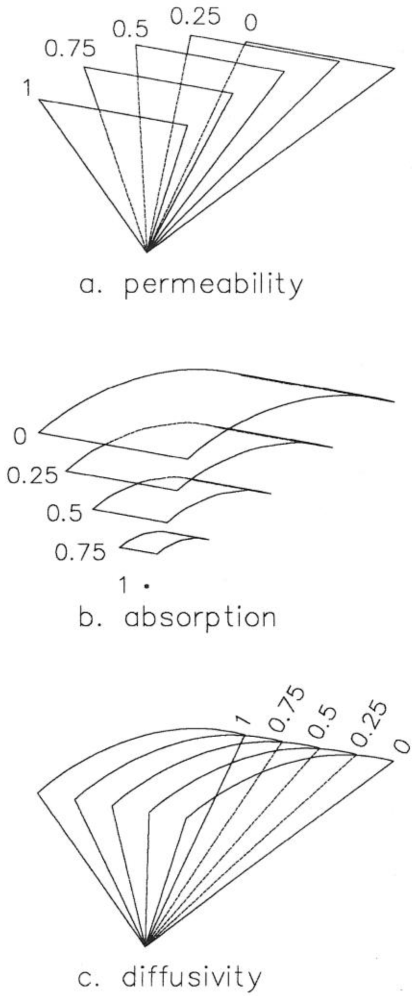

Fig. 2: Planes of constancy for each variable or dimension.

Diffusivity refers to the proportion between the subjective quantities of light seen by diffuse and regular re-emission. The pair diffusivity/regularity forms the opposite sides of this variable.

A certain sensation of cesia can be described by a set of three numbers indicating permeability, absorption, and diffusivity (in this order) as perceived. For instance, 0/0/1 is the sensation of a perfect opaque white, 0/0/0 is the sensation of a perfect mirror, 1/0/0 is the sensation of perfect transparence, 1/0/1 is the sensation of perfect translucence, 0/0.5/0.25 is the sensation of an opaque medium dark glossy surface.

4. The solid of cesias

All the sensations of cesia are arranged in a three-dimensional model whose vertexes constitute the locus of the five primary sensations (Figure 1).

Within this solid, each triangular plane as shown in Figure 2a is the place for cesias with constancy of permeability. Each horizontal curved plane as shown in Figure 2b is the place for cesias with constancy of absorption. Each plane as shown in Figure 2c is the place of cesias with constancy of diffusivity.

The solid of cesias shares a feature with the traditional color solids; this is the line on which the variation of absorption occurs from a diffuse reflecting surface to black. The variable absorption (or its opposite, luminosity) in cesia, is similar to the variable called value, lightness, darkness, or luminosity in color. The difference is that in cesia, this dimension is also applied to transparent, specular, and translucent sensations, which are not taken into account in the traditional systems of color.

The variables, notation, and solid of cesias are more thoroughly explained in a previous publication [4]. Let us turn now to some new issues.

5. Scales of cesias

Eight scales of cesias with five steps each were built. The scales, defined by their opposite poles, are:

Scales of absorption/luminosity

1) matte white – black
2) specular – black
3) translucent – black
4) transparent – black

Scales of regularity/diffusivity

5) specular – matte white
6) transparent – translucent

Scales of permeability/opacity
7) specular – transparent
8) matte white – translucent

The variation of sensation in each scale can be expressed in one direction (e. g. sensation of absorption) or in its opposite (sensation of luminosity). Going from one pole to the other in the scale, one of the sensations increases while the other decreases. The steps in each scale are

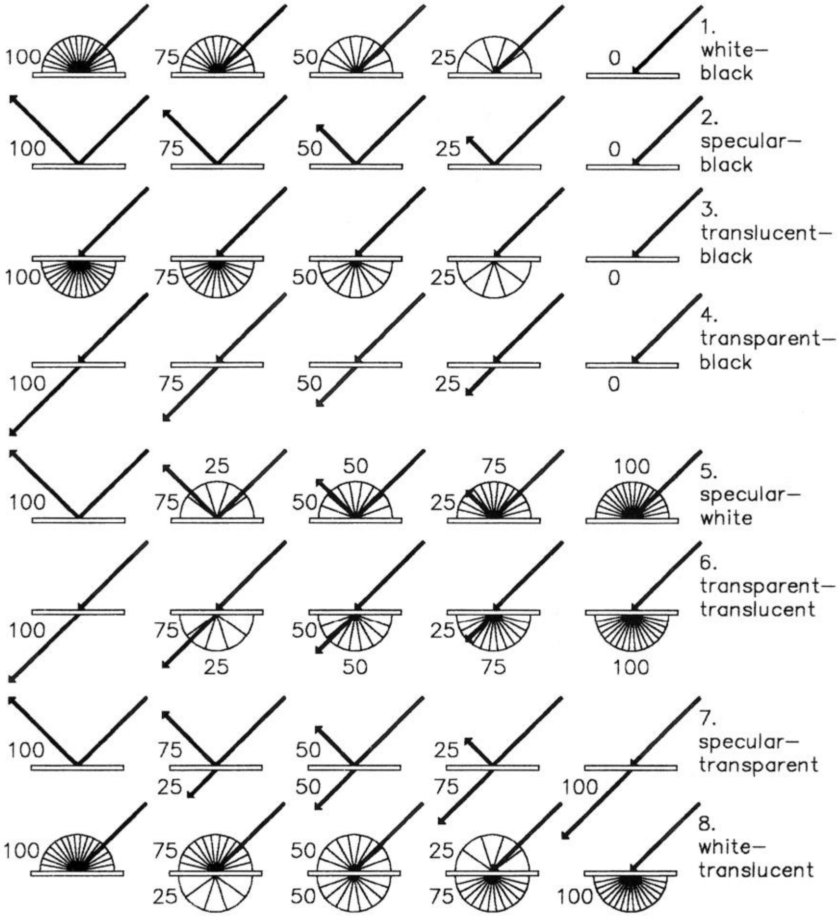

Fig. 3: Iconic representation of the eight scales of cesias. The numbers represent magnitudes of sensations in percentages.

expressed by means of coefficients (0 – 0.25 – 0.50 – 0.75 – 1) or by means of percentages (0% – 25% – 50% – 75% – 100%). These numbers do not refer to the stimuli, they express magnitudes of sensations. This means that when we read 0.50 or 50% it is not to be assumed that the opposite stimuli in the scale are present in equal or half parts, but that the sensation experienced is such that it is perceived as the midpoint between the two primary sensations at the extremes of the scale.

The scales were built by means of disks rotating faster than the frequency of fusion. Each scale was made with five disks holding different sectors of two materials producing the stimuli for the two opposite primary sensations.

Figure 3 gives iconic representations of these scales. The actual sensations can only be held by direct vision of the spinning disks or evoked by photographs of them. A forthcoming paper [9] includes photographs as well as detailed information and data about the construction of the scales.

5.1: Numeric construction of the scales

The proportions of the stimuli, given by sectors of disk, were determined by a relation of a power function between sensation and stimulus, as expressed by the law of STEVENS [10].

$\psi = k\, ø^{ß}$
ψ : sensation magnitude
$ø$: stimulus magnitude
k : constant
$ß$: exponent

In our case, the problem was to calculate the stimuli corresponding to a scale of subjective magnitudes previously fixed. According to the observations made, uniform scales were obtained with the values of *ß* given in the following table, yielding the disk sectors for the five steps of the scales as shown below each scale (the sectors are measured in degrees):

Scales of absorption/luminosity

white-black		*ß* = 0.5		
360/0	202/158	90/270	23/337	0/360
specular-black		*ß* = 0.5		
360/0	202/158	90/270	23/337	0/360
translucent-black		*ß* = 0.5		
360/0	202/158	90/270	23/337	0/360
transparent-black		*ß* = 0.5		
360/0	202/158	90/270	23/337	0/360

Scales of diffusivity/regularity

specular-white		ß = 1		
360/0	270/90	180/180	90/270	0/360
transparent-translucent		ß = 0.7		
360/0	239/121	134/226	50/310	0/360

Scales of permeability/opacity

specular-transparent		ß = 1.6		
360/0	301/59	233/127	151/209	0/360
white-translucent		ß = 1		
360/0	270/90	180/180	90/270	0/360

5.2: Dispositions of elements

1) The white-black scale is a typical scale of opaque grays. It is made with sectors of white and black cardboard in the disks.

2) The specular-black scale is made with disks holding sectors of a mirror and black cardboard. It can be observed by placing a pattern in front of the disks. The disks reflect the pattern but the reflection decreases while the absorbent sector grows.

3) The translucent-black scale is made with disks holding sectors of a translucent material (e. g. film polyester) and black cardboard. This scale can be seen by illuminating a pattern behind the disks so that the light comes from its surface. At the translucent end, the light is seen by diffuse transmission (the pattern is completely blurred), then the transmission decreases as the black sector grows.

4) The transparent-black scale is made with disks holding sectors of black cardboard and open sectors (air). It can be seen with the same arrangement of things of the previous scale. The regular transmission of light decreases as the black sector grows.

5) The specular-white scale is made with disks holding sectors of a mirror and white cardboard. It can be seen by placing a pattern in front of the disks. The specular reflection turns diffuse reflection as the white sector grows.

6) The transparent-translucent scale is made with disks having sectors of film polyester and open sectors (air). It can be seen by illuminating a pattern behind the disks so that the light comes from its surface. The transmission goes from regular to diffuse as the translucent sector grows.

7) The scale specular-transparent is made with disks holding sectors of a mirror and open sectors (air). It can be observed by placing a pattern of parallel lines behind the disks and another one, with lines perpendicular to the former, in front of them. As the open sector grows the specular

reflection turns regular transmission. At the midpoint of the scale a checked pattern of equal intensity in both directions appears. From this point to both extremes, the intermediate sensations are displayed.

8) The scale white-translucent is made with sectors of white cardboard and film polyester. It is particularly difficult to evaluate, because – as in the previous scale – the subjective quantities of light seen by transmission and reflection must be estimated but, due to the diffusiveness, this judgement cannot be made with the aid of linear patterns. The scale can be seen by placing a surface of a saturated color, far enough from white as regards its luminosity (an intense blue), behind the disks, and directing the illumination both to the rear and to the front of them. With this arrangement, the translucent extreme appears blue (the light comes from the rear by diffuse transmission) while the other extreme looks white (the light comes from the disk by diffuse reflection). The scale is evaluated as a gradation from hue to white.

5.3: Other scales

The scales described are only the eight ones that appear at the edges of the solid of cesias. Two more scales exist that can also be included among the basic ones. They are the transparent-white and specular-translucent scales, which appear in the diagonals of the upper surface of the solid. In addition to these, many other scales can be marked by tracing lines between any pair of points in the atlas.

Examples of scales of cesia can be observed in everyday situations. GREEN-ARMYTAGE mentions some cases: the transparent-dark scale that is observed when one prepares tea, or when two sheets of polarizing material are rotated one in front of the other; the transparent-white scale formed by adding milk to water [2]. There are also other examples: when a mirror progressively mists over by the presence of steam, a specular-matte scale is observed; when the same happens while looking through a glass, a transparent-translucent scale is observed; a transparent-specular scale can be obtained by looking perpendicularly at a piece of glass and then tilting it progressively. Scales also arise by variation in the intensity of the incident light. If we look through a window while night is falling, we have a transparent-black scale (provided that the sun is the only source of light); if the glass of such a window is frosted, we have a translucent-black scale; if the light falling upon a white surface gradually diminishes, a white-black scale is observed; if the same happens upon a mirror, a specular-black scale can be seen.

6. Conclusions

Some assumptions exist which should be revised in view of the results obtained with the system of cesias.

HUNTER affirms that unlike colors, the geometric attributes of appearance, such as gloss, diffusion, translucence, and others, can hardly be organized and cannot be defined by any system of dimensions or coordinates [11]. The atlas of cesias, built on the basis of three variables, as well as the scales generated through it, prove that such a task is possible. GREEN-ARMYTAGE arrived independently to the same conclusion and also proposed an order system to organize what he calls “quality of surfaces” [2].

Although it is true that a *perfect* mirror does not possess color and that gloss masks color, it is clear that there are tinged mirrors and that the gloss can have tonality. This fact is explainable in terms of the system of cesias and the trichromatic theory, being the case of surfaces with spectral selectivity for the component of specular reflection.

According to HUNTER, “it is not possible to produce an equivalent gloss stimulus synthetically (as color stimuli are matched by mixtures of three standard lights)” [12]. The scales of cesia built by means of spinning disks prove that this aspect of the visual appearance of an object can be matched by the mixture of two or more primary stimuli.

6.1: Perspectives and applications

At present, designers (industrial and graphic designers, architects, etc.) can benefit from the use of systems for the description and measurement of color. The situation is quite different for these other visual signs we call cesia. Though in some cases, such as in the glass industry, coefficients and percentages are used to express the values for absorption or transmittance of the material, and even that instruments exists to measure the geometric attributes of appearance, all these aspects are taken in isolation. The system of cesias allows for the integration of the variables (permeability, absorption, diffusivity) which, taken in connection, can define the characteristics or behavior of a material as regards a certain type of radiation in certain conditions, as well as the kind of visual sensation produced (independently of the color sensation). This integration addresses also one important issue in design, that is, the development of principles of harmony in the combination of cesias (equivalent to those rules proposed for the combination of colors).

Finally, it is to be noted that scales of cesia can be developed not only by situating an opaque white in the locus for matte opacity but also with any other opaque color in this place. In the latter case, permeability, absorption, and diffusivity are taken for the selective radiation of the color in question. In other words, any color can be led to the primary sensations of cesias, that is, to the extremes of transparence, translucence, specular reflection, diffuse reflection, and absorption, traversing all the intermediate steps and without losing its tonality. The primary sensations

– except for the absorption (black) – may have spectral selectivity. The different cesias in which a color may appear can be adequately explained in terms of the trichromatic theory by referring the variables or dimensions of cesia to each primary component (violet, green, red).

References

[1] HUNTER, R. S., The Measurement of Appearance. John Wiley, New York, 1975, p. 4.

[2] GREEN-ARMYTAGE, P., Colour and other aspects of appearance. Paper presented at the Second National Conference of the Colour Society of Australia, October 1989.

[3] JANNELLO, C., Fundamentos de Teoría de la Delimitación. Facultad de Arquitectura y Urbanismo, Universidad de Buenos Aires, 1984, p. 1.

[4] CAIVANO, J. L., Cesia: A System of Visual Signs Complementing Color. Color Res. Appl. **16** (1991), pp. 258–268.

[5] Ref. 1, p. 247.

[6] LOZANO, R. D., El color y su medición, Americalee. Buenos Aires, 1978, p. 165.

[7] Ref. 6, p. 170.

[8] MUNSELL, A. H., A Color Notation. Munsell Color Company. Baltimore, MD, 1946, p. 58.

[9] CAIVANO, J. L., Appearance (Cesia): Construction of Scales by Means of Spinning Disks, forthcoming.

[10] STEVENS, S. S., Psychophysics. John Wiley, New York, 1975, pp. 13–17.

[11] Ref. 1, pp. 12 and 59.

[12] Ref. 1, p. 65.

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