FUTURE DIRECTIONS FOR RESEARCH - COLOUR COMBINATION AND TOTAL APPEARANCE

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INTRODUCTION

Most attention in colour research has been devoted to isolated colours. Physicists have studied individual sources of radiant energy and uniform surfaces which absorb and reflect different wavelengths of light to the same degree. Physiologists have studied the sensitivity of the human eye to these lights and surfaces. Psychologists have solicited responses to individual colour chips - are they beautiful or ugly? old fashioned or modern? warm or cool?

This work has made it possible to draw all kinds of conclusions about the nature of things and the workings of the human eye and brain. It has also made it possible to produce and reproduce coloured images and to match the colour of one material with that of another. And it has provided some useful guidelines for designers wishing to communicate particular ideas or feelings. But for the most part all this has been study of what is essentially an artificial world.

Objects are not just red, blue or yellow; nor are they just pale blue, dark blue, dull blue or vivid blue. They are also rough or smooth; transparent, translucent or opaque; matt, glossy or metallic. Furthermore we hardly ever experience colours in isolation and the appearance of things changes as time passes and as we move about.

For example, the redness of a snooker ball is a very small part of the story. It is also spherical and glossy and it is seen from different angles against the textured green surface of the table in endlessly different relationships to the sides of the table and the other coloured balls. It is the whole picture that a snooker player sees. When lining up each shot and preparing to strike the ball the player is guided by the relative positions of the different colours and also by the degree of shine on the balls and the texture of the playing surface.

Painters are also concerned with the whole. They must constantly monitor the effect of each brushstroke on the developing painting. As Matisse [1] wrote: "...each new stroke diminishes the importance of the preceding ones." And Patrick Heron [2]: "... differing colours on a flat surface pull and twist against each other .... all sensation of colour is relative ..."

It has been useful to deal with colour separately in the laboratory, but if a theory of total appearance is the objective, more research in other directions is needed. Texture and surface quality need to be understood as thoroughly as colour. Then attention can be focussed on the whole scene, not only on the interaction of colours alone but on the interaction of all aspects - textures, surface qualities and shapes as well as colours - and on the way that lighting, movement and context can change everything.

ASPECTS OF APPEARANCE OTHER THAN COLOUR

At our 1989 conference in Melbourne I spoke about "Colour and Other Aspects of Appearance" [3]. The other aspects were texture and what I included under the general heading of "surface quality" - transparency, opacity, gloss, metallic lustre etc. I also proposed a tentative model for organising scales of transparency. What I didn't know was that something similar (and more thoroughly resolved) had been developed in Argentina. I had also forgotten what I had not properly understood at the time - the Planets-Colour-System first published in 1983 by Michel Albert-Vanel.

A General Theory of Design

José Caivano's article "Cesia: A System of Visual Signs Complementing Color" appeared in *Color Research and Application* in August 1991 [4]. From this, and from other articles sent to me by Caivano, I learned about the *General Theory of Design* developed in Argentina. Work on this theory was initiated by César Janello. The theory, described briefly by Caivano [5], has four sub-theories each of which has its own structure modelled on the structure of a colour order system. *Colour* itself constitutes one of these sub-theories. The other sub-theories are *spatial delimitation*, *texture* and *cesia*.

Colour. The favoured models for colour are the three dimensional colour solids of Munsell [6] and Pope [7].

Spatial delimitation refers to the configuration of an object - spherical, conical, square, irregular hexagonal etc. The model has been described by Caivano [5].

Textures vary from rough to smooth. They are also characterised according to the extent to which the textural elements are closely packed or widely spaced and according to whether they are linear like corrugated cardboard, non-linear like sandpaper or somewhere in between. The model for texture has been described by Janello [8].

Cesia is a new word derived from Janello's first name, César. He proposed the word in the absence of any other to embrace such phenomena as gloss and transparency. Caivano has presented a refinement of his model for cesia [9].

In the model of cesia there are five "primaries":

1) Clear transparence
2) Translucence (translucent white)
3) Diffuse reflectance (opaque, matt white)
4) Specular reflectance (mirror-like appearance)
5) Complete absorbence (black)

They are located at the corners of a three dimensional solid and are connected by scales.

The red snooker ball can be used to test this General Theory of Design. It can be given a Munsell notation to locate it in the colour model. Being smooth it would be at a zero point in the texture model. And its position in the cesia model, since it is opaque and glossy, must be somewhere between diffuse reflectance (matt) and specular reflectance (mirror-like or metallic).

The Planets-Colour-System

The Planets-Colour-System deals with colour but also with the other aspects of appearance - transparency and opacity, gloss and matt. And it makes a distinction between illuminant colour and object colour. It will be described in more detail following the discussion on colour combinations.

Tincture

Earlier this year [10, 11] I suggested that it would be useful to have a word that would refer to all aspects of appearance, apart from shape, which could then be used when describing an object. I proposed the adoption of the word "tincture". In heraldry "any of the metals, colours or furs used in coats of arms" [12] is a tincture. In this sense, therefore, the word includes colour, texture and surface quality (cesia). My proposal is to revive and expand this meaning beyond the limited range of heraldic tinctures so that one could admire the tincture of someone's dress and be understood to mean the texture and any property of glossiness or transparency as well as the colour of the material from which the dress was made.

Measurement

The measurement of "appearance", as distinct from colour, was pioneered by Richard Hunter [13]. He focussed on degrees and kinds of gloss which he categorised and which he was able to measure with some success. Now that metallic and pearlescent paints have been added to matt and glossy paints a lot of work is being done to develop and standardise new kinds of measuring equipment so that it may be possible to establish whether or not two surfaces will match. These efforts, and the issues involved, have been described by Allan Rodrigues [14].

COLOUR HARMONY

A great deal has been written about how colours should be combined and what combinations are "harmonious", but there seems to have been surprisingly little in the way of systematic study.

A useful introduction to ideas about colour harmony has been provided by Whitfield and Slatter [15]. One problem is the meaning of the word harmony itself. If it is "a consistent, orderly, or pleasing arrangement of parts ..." [12] it is a logical minefield. What is "orderly" may or may not be "pleasing" and what is "pleasing" may or may not be "orderly". And there are the questions: whose order? and: pleasing to whom?

Chevreul proposed ideas about colour harmony which have been enormously influential. They have been accepted almost as God-given in spite of Chevreul's own disclaimer: "... I do not pretend to establish rules based upon scientific principles, but to enounce general propositions, which express my own peculiar ideas."[17] His ideas may, indeed, have general validity but as far as I know they have not been systematically tested.

Ostwald believed that "harmony equals order". Egbert Jacobsen elaborated Ostwald's theories in his book *Basic Color* [18]. The order is tied absolutely to Ostwald's colour solid which raises questions about carts and horses.

Moon and Spencer used a different colour solid, that of Munsell, when they developed their mathematical formulae for colour harmony. Their work is discussed by Whitfield and Slatter. Apparently subsequent experiments have not supported the propositions of Moon and Spencer. Perhaps their formulae would work better if applied to the Ostwald solid.

Johannes Itten is the author of *The Elements of Color* [19], perhaps the most widely used textbook on colour theory in the world. Like others before him, Itten placed great emphasis on the notion of "complementary colours". He adopted Runge's colour sphere [20], with the colour circle as the "equator". His complementary colours are placed opposite to one another which controls the spacing of hues in the circle. Any pair or group of colours in the sphere which can be connected by a line or which occur at the corners of a regular geometric figure which has mid grey at its centre of gravity is supposed to be harmonious. The hue spacing is, therefore, crucial. Itten claimed support for his theory from Science: "The concept of color harmony should be removed from the realm of subjective attitude into that of objective principle.... the afterimage always turns out to be of the complementary color.... colors [lights] are harmonious if they mix to give white.... colours [paints] are ... harmonious if their mixture yields a neutral gray." This might be quite convincing if these three definitions gave the same pairs. Since they don't, the theories they are supposed to underpin lose credibility.

Although such theories of colour harmony have shaky foundations they enjoy considerable appeal and many people have found them helpful. They need to be tested. But I agree with Arthur Pope's comment in relation to the work of Moon and Spencer (quoted by Whitfield and Slatter): "In the discussion of colour harmony in the past there has been too much of a tendency to lay down rules which must be followed. There are no rules; there are only possibilities."

COLOUR EXPERIENCE

Instead of starting with a colour solid and making unfounded claims, based on personal opinion, about what a particular kind of colour combination might mean, Uri Feldman has worked in the opposite direction [21]. He started with words that might be used to describe a particular colour combination and then invited several observers to record their responses to computer-generated images. The images were two-colour combinations within a square grid format which he called "boggles". With such a procedure it would be possible to find out what colour pairs were judged to be most harmonious and then look to see where the colours would be located in a given colour solid. Perhaps it would turn out, after all, that earlier theorists were right. Perhaps the colour pairs judged to be most harmonious would be "complementary" by one definition or another. But only then could one claim real authority for statements that such pairs are more harmonious than others.

Feldman, however, was not primarily concerned with colour harmony. His aim was "to evaluate how colour experiences are *established*, how experiences are *described*, and how experiences *relate* to each other." He worked with paired adjectives, such as quiet-loud, which might refer to colour experiences as "low magnitude" or "high magnitude". These were at either end of a seven step scale. His observers used this scale to rate the boggles and it turned out that their judgements were quite consistent. This made it possible to establish equivalence between two quite different boggles and, by locating the colours in a colour solid, to see what different kinds of relationships produced impressions of equal magnitude. The colour solid he used was that of Munsell.

Given that hue steps in Munsell are not equal to value steps or chroma steps, Feldman's work makes it possible to establish links. For example one boggle might have both colours of the same hue and the same chroma but different value. Another boggle might have both colours of the same hue (and the same hue as those in the first boggle), but the colours might be of different chroma but the same value. If the boggles are judged to be equal in magnitude it is possible to establish a relationship between value steps and chroma steps.

A THEORY FOR COLOUR COMBINATION

Las Meninas by Velasquez, *Red Interior, Still-life on a Blue Table* (referred to hereafter simply as *Red Interior*) by Matisse, *Black Square and Red Square* by Malevich and *White on White*, also by Malevich, provoke very different responses. Any system for recording and communicating colour combinations must keep description and evaluation very firmly apart.

A structure for describing the whole that one chooses to focus on - a painting, a garden, a motor car - has been developed and described by Anders Hård [22]. This model has four dimensions. Hård makes it clear that his intention is "not to make a cookbook of nice colour combinations but to outline factors that can be handled in a colour composition". He distinguishes between colour *discrimination*, which enables us to identify objects as separate from their backgrounds, and colour *identification* whereby we can determine, eg., whether a tomato is ripe or not.

Interval is the first dimension of the model. It deals with colour discrimination. There are three sub-dimensions:

1) Border distinctness. The borders separating the colour areas are clearly more distinct in *Las Meninas*, *Red Interior* and *Black Square and Red Square* than they are in *White on White*.

2) Kind of pair attributes. Most of the figures in *Las Meninas* are dressed in black and white. These two main attributes define the kind of border.

3) Size of the kind. The size of the white/black borders in *Las Meninas* is clearly greater than the white/white border of *White on White*.

Chord is the second dimension. This deals with colour identification and also has three sub-dimensions:

1) Complexity. This is determined quite simply by the number of different colour attributes. An art critic might regard *White on White* as a "complex" work, but for the purposes of this purely descriptive model, and with its single attribute of whiteness, it is not as complex as *Las Meninas* or *Black Square and Red Square* with their three main attributes of whiteness, blackness and redness. More complex still in this sense is *Red Interior* which has all the six possible attributes - whiteness, blackness, redness, greenness, yellowness and blueness.

2) Attribute content. This again is purely descriptive. Ad Reinhardt's black paintings and *White on White* are equal in their minimal complexity but the content is different.

3) Relation type. This refers to the way in which the colours are related. For example, in *Las Meninas* the dresses of the little princess and her kneeling attendant are each mainly whitish, but one is slightly yellowish and the other has a hint of blueness and blackness.

Harmonics is the third dimension. If Interval is concerned essentially with questions of legibility and Chord with questions of identity, Harmonics might be described as dealing with questions of subtlety, perhaps as an extension of Chord.

Harmonics, like the first two main dimensions, has three sub-dimensions:

1) Area relation. The relative size and position of the colour areas can reveal profound differences where descriptions under Chord would be the same. *Black Square and Red Square* has the same three main colour attributes as *Las Meninas* but it is dominated by whiteness where *Las Meninas* is dominated by blackness.

2) Colour similarities. This goes beyond the main and secondary attributes (whiteness, redness etc.). There may be similarities of degree. Colours may be not only whitish, but *equally* whitish. Or there may be similarities of ratio where there is the same relative resemblance to, eg., red and blue, which would mean that the colours were of the same hue. Another possibility would be equal lightness (as distinct from whiteness [23]). This would mean that the least distinct border between each colour and the steps of the grey scale would be established at the same grey step.

3) Rhythm. This deals with the overall relationships. The extremes are chaos and uniformity.

Visual context is the fourth dimension. This is clearly important. For example, a particular pink, as worn by Barbara Cartland, communicates something very different when painted on a cement truck. However the number of possibilities is virtually infinite. This dimension is not built into the structure in a formal way but it has its place so that it is not forgotten.

Hård acknowledges that the theory is far from complete and that further experiment is needed to establish its validity. The work is continuing.

COLOUR MEANING

Hård's model could be used to describe colour combinations which had been designed to communicate particular ideas or feelings. This would make it easier to draw conclusions from the results of an exercise which I have set my students [24]. One task was to produce a colour combination within a square grid format to communicate some idea or feeling such as masculinity, femininity, youthfulness, maturity, excitement or tranquillity. Each colour combination was the opinion of the individual student but it was submitted to the other students and either endorsed or rejected. And as more and more students have produced similar combinations for the same meanings, confidence in the general validity of our results is growing.

A more focussed and systematic study is being conducted by Lars Sivik [25]. Having already mapped the meaning of individual colours in NCS colour space [26] he has turned his attention to the meaning of colour combinations using Hård's model. The first task was to reduce to a manageable number the descriptive words that might be used. 130 words

were tested for 22 colour combinations. Five factors, or dimensions, emerged from this: evaluation, articulation, lightness, warmth, and tradition/fashion. For ease of communicating his findings, Sivik developed what he calls a "two dimensional representation of a semantic space of colour combinations". Here he has four pairs of opposing groups: Warm-Cold, Soft-Hard, Harmonious-Dynamic and Monotonous-Stimulating. The Soft group includes such of the remaining 130 words as motherly, graceful, delightful and cosy. Similar colour combinations would have been selected for all these meanings. In the opposing Hard group are words like powerful, ugly, cruel and determined.

THE COLOUR IMAGE SCALE

If it is possible to have a dictionary for translating between French and English or between Swedish and Japanese, it might also be possible to have the equivalent of a dictionary for translations between verbal languages and the visual language. The Color Image Scale has been developed to serve just such a purpose. Its development by Shigenobu Kobayashi and his team in Japan has been described by Kobayashi [27]. He has also produced two small books which make the Color Image Scale accessible and useful to a wider audience [28, 29].

Hue and Tone System

The colours used in the Color Image Scale are from the Hue and Tone System, a simplification of the ISCC-NBS method of naming colours [30]. The Munsell solid is divided into 125 zones, each zone being represented by a single colour. For each of ten hue segments there are twelve "tones", a tone being a particular combination of value and chroma. (The concept of tone used here is roughly equivalent to the NCS concept of nuance, except that a nuance is a particular combination of whiteness, blackness and chromaticness rather than value and chroma.) The tones are identified by such names as "vivid", "pale", "deep" and "greyish". In addition to the chromatic zones there are five achromatic zones for whites, pale greys, medium greys, dark greys and blacks. For the Color Image Scale these five achromatic zones are further subdivided and their number increased to ten. The "vocabulary" of single colours in the Color Image Scale is, therefore, 130.

Images

For its verbal vocabulary the Color Image Scale has 180 words or phrases which stand for particular *Images*. These images include "festive", "friendly", "dignified", "old-fashioned" and "sweet-and-dreamy".

The colours are organised in a three-dimensional space which has three axes: Warm-Cool (left to right, determined by Munsell hue); Soft-Hard (top to bottom, determined by Munsell value, white being softest and black

hardest.); and Clear-Greyish (front to back, determined by Munsell chroma). This three-dimensional space has been collapsed into a two-dimensional space with only the two axes Warm-Cool and Soft-Hard. This means that colours from different points on the Clear-Greyish axis can be on top of each other in this two-dimensional space. This might be expected to distort things but the two-dimensional space seems to work quite well.

The Image Scale

The 130 individual colours were matched up with the 180 images. For example the most festive colour is a vivid orange. Strong yellows are friendly, dark greyish blues are dignified, deep olive greens are old-fashioned and very pale pinks are sweet-and-dreamy.

If the colours in the two-dimensional space are replaced by their verbal images the result is a semantic space not unlike that developed by Sivik. Now it is possible to investigate what combinations of colours might communicate those images, a combination of colours being potentially much more expressive than a single colour on a white background.

The extensive research involved matching words to colours and also proposing colour combinations to match words, the latter process being similar to the exercise I set my students. In the colour combinations some colours migrate a long way from the positions they occupy in the space as individual colours. "Festive" orange, combined with other colours, can contribute to images that are "casual", "flamboyant" and "forceful". Contrast plays an important part.

The Color Image Scale can be extended to include materials, textures and patterns through the medium of the images. Delicate lace, frosted glass and small floral patterns would occupy the same area as sweet-and-dreamy pale pink since they communicate the same image. The Color Image Scale, therefore, can accommodate all those aspects of appearance which I am proposing to unite under the umbrella concept of tincture. And it could go further to include shapes, objects, spaces and perhaps even people.

ORDER FOR COLOUR COMBINATION

The section headed "Systems of Color" in *The Color Compendium* includes an essay by Michel Albert-Vanel on his Planets-Color-System [31]. He first published descriptions of the system in 1983 [32, 33, 34]. He refers to our everyday experience of "groups of colours" and points out that conventional colour order systems could not even accommodate something as simple as an autumn leaf with its subtle gradations.

Albert-Vanel's classification of colour groups has some points of similarity to Hård's model for colour combinations. Like the Natural Colour System - NCS, which is the reference structure for Hård's model, the Planets Color

System also incorporates Hering's theory of oppositions: red-green, yellow-blue and white-black.

Polychromy is the key to a colour group. If redness, greenness, yellowness and blueness are equally dominant, polychromy is high. The opposite of polychromy is monochromy, where one hue only is present. Each colour in a group can be plotted on a diagram in relation to the red-green and yellow-blue axes. The centre of gravity of these colours on the diagram is what Albert-Vanel calls the "entropy point". Between the centre and the edges of the diagram are scales of polychromy, from maximum at the centre to the minimum (monochromy) at the edges. By establishing the entropy point, the position of a colour group on the polychromy - monochromy scale is also established. Matisse's painting *Red Interior* is high on the polychromy scale, but biased towards red. *Las Meninas*, with only redness and a hint of yellowness to relieve the dominant blackness and whiteness, is more strongly biased towards red and is very low in polychromy.

Tone (Albert-Vanel's word for **Hue**). The dominant hue of a colour group that is not perfectly polychrome is also established by the position of the entropy point on the diagram. The prevailing hue (not necessarily the prevailing colour) in *Red Interior* and *Las Meninas* is red.

Saturation. When the whiteness and blackness of a colour group are taken into account another centre of gravity can be established - on a scale of saturation. In a colour group of maximum saturation there would be no whiteness or blackness. At the zero end of the saturation scale there would be no redness, greenness, yellowness or blueness. The prevailing saturation of *Red Interior* is very high, in *Las Meninas* it is very low.

Brightness or **Lightness.** The overall centre of gravity of the colour group can be related to the grey scale to establish the prevailing lightness. The prevailing lightness of *Red Interior* may not be as high as the highly saturated colours might suggest, but it is somewhat higher than that of *Las Meninas*.

Contrasts of hue, saturation and lightness can also be plotted on scales. The contrasts of hue are much greater in *Red Interior* than in *Las Meninas*. Since both paintings have some areas of highly saturated colours as well as areas of white and black they are both high on the scales of saturation contrast and lightness contrast.

Conjuncture. There are 63 possible combinations featuring one or more of redness, greenness, yellowness, blueness, whiteness and blackness. These can be presented on a matrix of pie charts, each pie chart being a means of categorising a colour group. *Las Meninas* and *Black Square and Red Square* would both be in the category identified by the red-white-black pie chart. *White on White* would be identified by the all white pie chart and *Red Interior* by the red-green-yellow-blue-white-black pie chart.

Other dimensions. Albert-Vanel is conscious of the difference between coloured lights and coloured surfaces, between glossy surfaces and matt surfaces and between transparent surfaces and those that are opaque. Scales for these are also incorporated in the system.

Semantics is the final consideration and takes account of the role of context. As Albert-Vanel says: "... it does not matter if a triangle is painted red or green, but a figure will resent being painted green."[32] He also recognises a kind of hierarchy of abstraction. At one end is the world around us, at the other end are isolated colours. In between are sculpture and the realism of paintings such as *Las Meninas*, the simplified shapes of recognisable objects in such paintings as *Red Interior* and the non figurative juxtapositions of coloured shapes such as those in *Black Square and Red Square* and *White on White.*

TOTAL APPEARANCE

A popular event at many schools of art and design is a "colour lunch". The students who prepare the food use vegetable dyes which change the appearance without altering the flavour. Purple potatoes, green wine and blue cake may be quite wholesome but they usually remain untouched. A colour lunch reinforces dramatically what most people know already, that we pay very close attention to the colour of the things we eat. In fact food technologists go to great lengths to maintain the "natural" colour of food that might otherwise change colour in storage; vegetable dyes are used to enhance rather than detract from the visual appeal of the food. However it is not colour alone that is liable to change during storage, nor do we base our judgements about food on colour alone. John Hutchings has stressed the importance of other aspects of appearance [35].

Hutchings regards the use of the word "colour" for all aspects of food appearance as unfortunate. Apparently the changes that occur in fish processing may be treated as changes in "colour" even though they are entirely due to translucency effects. Hutchings refers to Hunter's work on appearance measurement and recommends such an extended approach to the food industry. Perhaps the word "tincture", as I have defined it, could be useful for describing food products if "appearance" is too general and "colour" too narrow.

Hutchings refers to the role of appearance in our total experience of food and the overlaps that occur between the senses. The visual properties of shape, colour, texture and cesia (gloss, translucency etc.) combine with smell and contribute to our anticipation of an enjoyable meal, which may then be realised in the taste of the food and also in the tactile properties, the physical texture referred to as "mouthfeel".

Beyond these properties of the food itself Hutchings extends the concept of appearance to include the properties of the environment. Food has an *On Shelf Image*, a *Preparation Image* and an *On Table Image.* These images derive from:

1) Optical properties: Colour, translucency, gloss, uniformity, visual flavour.
2) Physical form: Shape, size, surface texture, visual consistency.
3) Mode of presentation: Product description, packaging, contrast phenomena, illumination.

Earlier this year Hutchings presented a development of these ideas in his paper *The Concept and Philosophy of Total Appearance* [36]. He proposed an approach to the analysis of complex scenes using a restaurant as an example. Our experience includes not only the food and drink but also the table setting, furniture, decor, lighting and atmospheric conditions as well as the other occupants of the restaurant. He suggests that these factors can be assessed for their relative importance and that such analysis can guide the planning of a new establishment.

SUMMARY

There are so many aspects to total appearance, with so many possible permutations and combinations, that any serious attempt at developing any kind of coherent theory must once have seemed quite out of the question. However the work described here has shown that such a theory is not only a possibility but also that it is potentially very useful.

The models overlap in many respects, having many factors or dimensions in common. Some models are more tightly structured than others and offer more opportunity for measurement (however wise such measurement may or may not be). Hutchings's concept is perhaps the most ambitious in scope but there are many details to be worked out. Janello, Caivano and their colleagues have made great contributions to our understanding of some of the details. Hård, Kobayashi and Albert-Vanel have contributed to our appreciation of the complex relationships that can exist.

As the models are used it is likely that they will be modified and refined. Features of one may be incorporated in another during the process of evolution. This work should help put an end to back-to-front theories of colour harmony. With the emphasis on description rather than evaluation the models make it possible to test hypotheses. For designers who are used to relying on their own intuition, however sound, or on the opinions of theorists like Chevreul, however wise, it will be possible to make decisions based on something more objective - the findings of researchers like Feldman, Sivik and Kobayashi.

Perhaps the most valuable aspect of this work is that it raises awareness. There are many more dimensions to appearance than the dimensions of colour and our experience of the real world is not of single stimuli but combinations. There is a great deal of work to be done, investigating more of the bits and the different kinds of relationships, but as this work proceeds it is important not to lose sight of the big picture.

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