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**COLOR HARMONIES IN LE CORBUSIER ´S PURIST
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COLOR HARMONIES IN LE CORBUSIER'S PURIST ARCHITECTURE BASED ON SALUBRA *CLAVIERS* FROM 1931.

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ABSTRACT

We have carried out a new study of the color combinations selected by Le Corbusier in *les claviers de couleurs* for the Salubra wallpaper company in 1931, by analyzing them in the color space of the Natural Color System (NCS), which allows us to understand the perceptive variables of colors (hue, blackness and chromaticness) as well as their harmony criteria.

Regarding the perceptive variables we have discussed the selected *hue* ranges in relation to other color proposals of Le Corbusier himself, and we have shown the extensive presence of earthy hues, or the noteworthy absence of other colors such as yellows, violets, black and white. We have also analyzed the *chromaticness* of colors, which is generally low, and the *blackness*, also very limited.

In relation to the harmony criteria, we aim to find out the underlying order in the color combinations by studying the similarities and contrasts of their perceptive variables. We demonstrate graphically, by a navigable three-dimensional model, and with statistical support, some principles of harmony such as the preference of colors with equal *chromaticness*, the search of some contrast in *blackness*, or the usual resource of contrasting cool with warm colors, something slightly different to the contrast of complementary colors.

We have also discussed other compositional criteria held by Le Corbusier to use color in his Purist architecture, and which are related to the position and proportion of the surfaces to be colored, the connotations associated to different hues, or the use of plain colors, among others.

Keywords:

Architecture, Color harmony, Natural Color System

PROBLEM

Modern architecture developed between 1920 and 1960 was erroneously identified with the almost exclusive use of white color, and it was exemplified with the Purist architecture of Le Corbusier¹. However, not any building by Le Corbusier "was only white, anyway"².

Le Corbusier studied the architectural color with much interest, and he uses it in his work in a very appropriate way. In 1931, the Salubra wallpaper company, based in Basel (Switzerland), commissions him to make a first color charts collection for architecture that is completed in 1959 with a second version. The first of these collections was thought as a harmonic series, in a similar way to the distribution of the sounds in a piano, hence its designation as "*claviers de couleurs*"³. In 1997, both color collections are reissued together with Le Corbusier's unpublished text "*Polychromie architecturale*", dated between late 1932 and early 1933⁴. This is, without doubt, the most important document for understanding the color in the work of the Swiss architect.

There are several authors who have carefully studied the Salubra color collection: J.L. Caivano explains its organization and use; M. Colli explains the order of colors in the claviers⁵; A. Ruegg analyzes in depth the charts along with the text *Polychromie architecturale*; and J. de Heer⁶ develops a thorough study of the chromatic aspects in the writings and the Purist architecture of Le Corbusier, showing the high degree of freedom in the final color solutions in his buildings beyond the Salubra color keyboards.

However, there is a matter that has not been worked so far, which consists of an analysis of the combinations of the selected colors in the keyboards, by using a standard color notation space as NCS, and which allows us to understand the colorimetric characteristics of colors and their harmony criteria. We aim to unravel the underlying order in the color combinations of the Salubra *claviers* by studying their perceptive variables in NCS: hue, blackness and chromaticness.

This analysis is consistent with Le Corbusier's thought, at least during his Purist period, which this collection of colors belong to. He believed that beauty in architecture responded to a series of universal laws based on numbers, which could be known and studied⁷. In fact, the architect developed a system of numerical proportions for the architectural elements based on the golden ratio and on the measures of an ideal person, known as *The Modulor* (1948 and 1953). In this regard, his approach to the

1
2
3 ideal beauty is linked to what we can consider a *positivist* paradigm and it is based on rational criteria of
4 order and proportion⁸.

5 Le Corbusier does not conceive the Salubra charts as an open system that could serve to combine
6 any color of nature, but as a sort of *manual*, very well delimited, with only 43 colors, that have all
7 guarantees to be "appropriate for architecture" and which he determines how to combine. Le Corbusier
8 does not search a classification system for all possible colors, but rather an instrument to restrict them and
9 guarantee their possible harmonies. Hence, the color charts are made in the manner of a piano keyboard,
10 in which the keys are limited but provide the basis of any musical harmony.

11 In any case, Le Corbusier limits the leeway to choose the architectural colors according to a
12 uniquely personal criterion of harmony, which can only be explained from his sensitivity as an architect
13 and a painter, as well as from his desire to rationalize the most of his creative processes. So our numerical
14 approximation will not let us build a true "chromatic Modulor", understood as an open and universal
15 system, but it will let us a more accurate approach to some harmony rules pointed out by other authors
16 regarding Le Corbusier's colors. For this purpose, we will greatly rely on Heer's work, which we consider
17 very rigorous and well documented.

18 EXPERIMENTAL METHOD

19
20 This study has been conducted from the documentation available at the Le Corbusier Foundation
21 in Paris, where the original color charts were visually and technically evaluated (contact
22 spectrophotometer Konica Minolta CM 700d, Munsell and NCS colorimeter)*. In the Foundation we
23 could access to the writings, letters, technical specifications of the works and other graphic and written
24 material, in which the architect reflects on the use of color in his work.

25 We focus on the first Salubra color collection from 1931, because it is much more appropriate
26 for the present study than the one from 1959. The first collection is the final answers to those interests
27 that Jeanneret and Ozenfant started to investigate in their text *Nature et création*⁹ in 1925, and it is the
28 culmination of the reflection on Purist polychromy and their searching for harmony laws. When the
29 second Salubra chart is published, the historical, personal and artistic context of Le Corbusier has
30 substantially evolved and he has abandoned much of the rationality of his initial thoughts, when he
31 considered that beauty was based on the search for order and formal clarity. The second collection
32 contains significantly less number of colors and they are not organized in *claviers*, while in the first
33 collection the possibilities of selecting colors are much higher. In fact, these color charts go with white
34 cardboard templates that allow us to isolate the samples of a keyboard in combinations of two, three or
35 four colors. By contrast, the collection from 1960 incorporates new colors but it does not give such
36 concise criteria to combine them.

37 Our methodology has consisted in extracting all possible color combinations in the collection,
38 which ended up being 312 combinations of 4 colors (936 pairs of colors), and to represent them in the
39 three-dimensional color space NCS. This representation is a navigable 3D virtual model that can be
40 observed from any point of view (fig 1). After that, we have made some diagrams where we have carried
41 out a visual and statistical analysis of the combinations, identifying whether there are harmony or contrast
42 criteria, that is, similarities or differences regarding the colors hue, blackness or chromaticness. To
43 process the information we have used usual Cad software for architecture, Autodesk Autocad, as well as
44 database management software, Microsoft Excel.

45 Figure 1

46 In a theoretical framework, the search of color harmonies has been carried out by following the
47 usual models of positivist paradigm, which are the closest to Le Corbusier's thought. On one hand, the
48 search of similarities among colors, as proposed by A. Munsell (1921) or later by J. Itten¹⁰ (1961); on the
49 other hand, the search of balances between opposite forces, as claimed by A. Munsell (1921) as well,
50 Chevreul (1839) or Goethe (1810), among others. We should mention Newton himself, who suggested
51 that color harmonies rely on proportional order of colors, in a similar way to the mathematical principles
52 that hold any musical composition. It is true that all color harmony models which are based on similarities
53 and contrasts have limitations, especially when they aim to give universal answers, valid for any context
54 or any observer, as Z. O'Connor correctly advises⁸. However, in the present case, they are very useful
55 because our aim is to better understand some color combinations that Le Corbusier himself already

56
57 * In the cases where the time had deteriorated the original color samples available at Le Corbusier
58 Foundation, like in the blue 32040, we have measured the color in the new version re-edited in 1997, as we consider
59 it a very good reinterpretation of the original shades.
60

considered harmonic. In any case, it is difficult to make the mistake of considering the Salubra charts as the universal solution to the problem of color harmonies in architecture, when even Le Corbusier himself does not seem to use them in a strict way.

ANALYSIS OF THE PERCEPTIVE VARIABLES OF COLORS IN THE SALUBRA COLLECTION FROM 1931

Analysis of the hue families

The 43 colors of the first Salubra collection are organized into 12 charts named *claviers*. Each one of them consists of three background colors, that we will name *valeurs de fond* following Le Corbusier's nomenclature, and two horizontal strips of *color tons* placed in a sequence that resembles a keyboard. To facilitate the selection of colors, charts are accompanied by white cardboards which allow isolating two *valeurs de fond* together with one or two *color tons*, so that the selected colors, with a maximum of four, should be observed isolated with a white cardboard. The fact that the cardboard is white is not a chance, and we will insist on the importance of white as a previous color, necessary for the architectural polychromy. Nor it is a coincidence limiting the maximum number of colors selected to four, as we will discuss later as well.

In the different color charts, it seems evident that the *valeurs de fond* give the 'pitch' to each *clavier* and they are somehow linked to the names that identify them: Space; Sky; Velvet I and II; Masonry I and II; Sand I and II; Landscape; and Checkered I, II and III. By means of an associative mechanism, the *valeurs de fond* are linked to a concept, an idea of secondary order. Thus, the blue colors are associated with the concepts of "Sky" and "Space", the ochre colors with the "Sand", the red ones with "Masonry" and the green ones with "Landscape". This associative role of color is evident in projects like the Housing State in Pessac (1931), where green is linked to the idea of a distant forest or a vegetal roof, blue to the sky background, and red is used to "fix" the facade as a *masonry* and to strengthen its presence.

Each color of the Salubra collection is denoted with reference numbers which indicate that they all derive from 14 initial colors, which we will be called *main colors*. From each one of these *main colors*, Le Corbusier obtained several extra nuances by adding more white and moving the brightest colors to a softer version with just three or four steps. Thus, the units of each reference number indicate the color saturation, while the tens and hundreds identify each of the 12 hue families. Following M. Colli's designation⁵: 00 and 01 for the Grays (001, 010, 011, 013), 02 for Ultramarine blues (020, 021, 022, 023, 024), 03 for Cobalt blues (030, 031, 032, 033, 034), 04 for Veronese greens (040, 041, 042), 05 for Yellowish green (050, 051, 052, 053); 08 for Oranges (080, 081, 081), 09 for Vermilion-reds (090, 091), 10 for Carmine reds (100, 101, 102), 11 for Red Ochre (110, 111, 112); 12 for Sienna (120, 121, 122, 123), 13 for Brown (130, 131) and 14 for Shadows (140, 141, 142, 150).

Selecting these 14 hue families and not any other, Le Corbusier wants to avoid colors that are not fully "architectural" and so that can neutralize the visual effect of architectural forms. In relation to the easel painting, Ozenfant and Jeaneret prioritized volumes and the drawing of shapes against color, and they wanted to avoid the destructive character of color which was criticized in other artistic movements such as *De Stijl*. Also in Architecture all impressionist effect of color which could distort the geometry of pure forms should be avoided.

Present colors

In a previous text¹¹ to the first Salubra color collection, Ozenfant and Jeaneret described three ranges of color for easel painting. The first was the *large gamma*, containing all those *constructive* colors that were used by the great painters of the history of art, from Michelangelo or Ingres, through Seurat or Cezanne, to the Cubists Picasso and Gris. These are well-liked painters because they all, from Le Corbusier's view, subordinated color to drawing and gave priority to the shape modelling by means of the *chiaroscuro*. They chose *disegno* versus *colore*, reinforcing the opposition between these two concepts, which was started in the Renaissance with Vasari and was extended till the end of the 19th century in France. The *large gamma* includes Yellow, Red Ochre, Earthy colors, White, Black, Ultramarine and the colors originated from those. The second is a *dynamic gamma* and, unlike the previous one, it contains colors that are not "static" but give the impression of continuous change of plane. The Lemon-Yellows, Oranges (Chrome and Cadmium), Vermilion, Veronese Green and light Cobalt Blue belong to it. The

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third is a *transitional gamma* that contains the Emerald Green and all Enamel colors, without constructive characteristics. Le Corbusier suggests that he just wants to use the *large gamma* (fig 2).

Figure 2

In the Salubra color charts, the criteria for selecting colors also reflects a desire to restrict them to only those which are truly architectural, but this time Le Corbusier talks about the selection of a *noble range*¹²: White, Black, Ultramarine, Blue, English Green, Yellow Ochre, Natural Sienna Earth, Vermilion, Carmine, English Red, Burnt Sienna Earth. Therefore, the initial distinction among the three ranges of color is abandoned and it can be seen that in first Salubra collection, Le Corbusier adds to the *large gamma*, without any difficulty, some colors belonging to the *dynamic gamma*, that is, the *"agile, restless gamma, which gives the sensation of continuous change"*.

If we look at the 43 selected colors existing in the first Salubra, in NCS notation, we see that approximately the half of them (17) belong to families included between R10B and Y80R, that is, cool colors, and the other half (17) belong to families located between G40Y and R80B, that is, warm colors. Grays and neutral colors (9) would be apart from them. As we will see later, the hue families in Salubra 1931 can be understood in terms of opposition between cool and warm colors, following a classification proposed by Le Corbusier himself, which assigns different architectonic qualities to both groups. We must note that warm ranges include only six hue families, organized around the Y80R red, while cool ranges contain twice the number of hue families, six around the R80B blue and six around the G30Y green. So, warm colors that are too close to yellow or violet are avoided (fig 3).

Figure 3

In addition, the warm ranges that Le Corbusier selects are mostly brownish, that is, with low saturation, and they can be explained by his desire to link them with natural pigments. For Le Corbusier, these colors extracted from earth are those that have accompanied architecture since its origin. They are "eternal" colors and differ from the chemically synthesized pigments, so popular in the paintings of the second half of the 19th century. However, we must recognize that these colors are excessively intense compared to the historical ones. Recent researches of historical centers of many cities, at least in the Mediterranean arc, show that traditional architecture contained widest ranges of color, with more yellowish hues, close to the Y30R or Y40R families, and generally with brighter shades¹³.

Absent colors

It is interesting to observe not only the selected colors existing in the first Salubra collection, but also the absent colors. One of them is black, which is replaced by other colors, quite dark, but that actually belong to other hue families: *Brown* and *Sienna*. There are three gray values which strictly belong to the family of neutral colors, N in NCS nomenclature (010, 011, 013) and which have three different values of blackness (20, 40, 65). However, the darker color is the brown (130) which belongs to the Y80R hue family.

The absence of white is also striking, being the most similar the 001, which is a yellowish shade that belongs to the Y30R family. The white color is absent precisely because it has an exceptional status. White is previous to polychromy, it is the necessary color to purify the look towards the architectural form, as Wigley¹⁴ states. Le Corbusier thinks that the white color is the necessary background for all other colors to take their meaning. So he says about the Villa Albert Jeannerette (Paris, 1923-1925): "*The base will be white; but we will paint two of the walls pale pink (clear burnt Sienna earth), another one opposite, pale green; the rest white, the ceiling white*"¹². The white color is the one of the stucco, or to the paint, that is applied directly to the ceilings and walls, that is the reason why it is not necessary to include a white painted paper in the Salubra collection. We note again that the cardboard used to select the *color tons* is white, and not a medium gray as it should be advisable to avoid the phenomenon of simultaneous contrast when observing a color. The architectural polychromy must be observed over the white color, but we can still go further, as Le Corbusier not only mentions the white as the necessary background, but also as the purpose itself, of all the chromatic organization. In this sense, Le Corbusier notes about the *Pavilion de L'Esprit Nouveau* (1925): "*the calcimine shines through the wall surface that is dark (burnt or natural terra-umbra), through a wall that is warm (ochres), through a wall that yields (blues, etc.)*"¹⁵. In this statement, it seems that Le Corbusier wants to work like the Impressionist painters, who arranged color accents around the white to emphasize its luminosity.

Also we note the absence of several color families, corresponding to greenish yellow and orange yellow, whose nomenclature would correspond with numbers 06 and 07 in the Salubra notation. Indeed, there are no colors between G40Y and Y60R hue families, with the exception of four shadow colors (060, 140, 141, 142). It seems as if Le Corbusier moves *cadmium yellow* ranges to earthy ones, rather dark, and *greenish yellow* ranges to *hardly yellowish green* ones. There is also an apparent absence in the hue families located between R80B and Y10B, that is, the violet colors, which are rejected from the Purist architectural consideration.

Color Id.	NCS Notation	Number of times combined	Claviers where this is a <i>valeur de fond</i> (times combined as a <i>valeur de fond</i>)
001	5 10 Y30R	110	Velvet 1, 2 and Variegated 3 (78)
122	10 20 Y60R	80	Wall 1 y Wall 2 (52)
131	30 10 Y50R	60	Sand 1 and 2 (52)
112	10 15 Y70R	52	Wall 1 and Wall 2 (26)
091	10 10 Y70R	52	Wall 1 and Wall 2 (26)
013	20 2 G50Y	50	Velvet 1, 2 (26)
121	30 30 Y70R	43	Variegated 2 (13)
120	60 20 Y80R	43	Variegated 2 (26)
011	40 0 N	41	Variegated 1 (13)
051	20 50 G30Y	40	Landscape (26)
110	40 40 Y70R	37	Variegated 2 (13)
032	20 20 B30G	34	Sky (26)
030	40 40 R90B	34	Variegated 1 (26)
082	5 15 Y60R	30	Sand 1, 2 (26)
022	15 15 R90B	30	Space (26)
090	30 60 Y90R	27	
020	30 50 R80B	27	Variegated 3 (13)
060	05 15 Y30R	26	Sand 1, 2 (26)
012	35 0 N	26	Velvet 1, 2 (26)
130	70 5 Y80R	25	Variegated 1 (13)
053	10 30 G40Y	25	Landscape (13)
033	15 15 B50G	25	Sky (13)
024	8 4 B50G	25	Space (13)
142	20 5 Y40R	23	
140	65 2 Y	22	
010	65 2 B	22	
050	40 40 G10Y	21	Variegated 3 (13)
141	40 5 Y20R	19	
034	10 10 B90G	19	Sky (13)
100	40 40 R	18	
021	10 30 R80B	18	
052	10 40 G40Y	17	Landscape (13)
023	10 15 B	17	Space (26)
111	20 30 Y70R	14	
102	10 20 Y90R	14	
041	20 20 B90G	14	
040	50 20 G	14	
123	10 10 Y50R	12	
101	30 50 R10B	12	
042	15 10 G20Y	12	
080	10 60 Y60R	8	
081	10 50 Y60R	4	

031	20 40 B10G	4
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In 1951, Le Corbusier corrects these absences of hue families in his new color palette, *the types couleurs* which he used in the *Unité d'Habitation*, the Swiss Pavilion, or other buildings[†]. In this palette, all colors of the spectrum are represented, including bright yellow, violet and black. When the second Salubra color collection is published, eight years after, some of these colors which were absent in the first version from 1931 appear: black (4320E), cadmium yellow (4320W) which belongs to the Y10R family, and also a very saturated yellowish green G80Y (4320F). In general, lighter colors are abandoned and highly saturated ranges are proposed. Curiously, violet is still not present.

As Ruegg⁹ notes, Le Corbusier's architecture which belongs to the period after the Second World War, is dominated by a strong coloration, sometimes in the form of *chromatic accents*. The pure black color is now located close to the white, when, at the beginnings, it hardly appeared as a surface (except certain floors made with black tiles), and, in general, the textures of materials start to become important. Definitely it is an evident evolution of architectural polychromy which becomes less rigid and more expressive.

Blackness characteristics of the colors

Most of the colors belonging to the Salubra collection have a low *blackness* value, between 10 and 30 (30 colors) or close to 5 (3 colors). The remaining ten colors are between 40 and 70 in *blackness*. As noted above, there is not a pure black color neither a pure white, being the brightest color the ochre 001 (Y30R), and the darkest one, the brown 130 (Y80R). The latter is followed in darkness by the *shadow*, *brown*, *sienna* and *gray* hues, to which we can add the *Veronese green* family.

Figure 5

We have already noted that in the first Salubra collection each hue family is formed from a *main color* to which white color has been progressively added to obtain two or three nuances. Thus, we note that for each of the 12 hue families, *gray*, *ultramarine*, *cobalt*, *Veronese green* and other, the darkest value always corresponds to the *main color* (010, 020, 030, 040, 050, 060, 080, 090, 100, 120, 130, 140). In no case nuances have been obtained adding black to these *main colors*. Moreover, these *main colors* end up being the most saturated of each hue family, in the most of cases. For example, there is no darker carmine than the 100 carmine itself, at its maximum degree of saturation, nor darker cobalt blue than the 030 blue itself, at its maximum degree of saturation, being both *main colors* of their respective hue families.

Heer⁶ questions the cause by which Le Corbusier does not mix *main colors* with black, but he does with white, and he notes that it could be a residue of the impressionistic idea, imported from painting, that black color is not in nature as such. But he also points to the fact that, in architecture, colors may already be "darkened" if we arrange them in a dimly illuminated area, by the effect of the cast shadows and the light interacting with the volumes. Obviously this is true but we must not forget that, on the contrary, an increased area of color itself tends to make it brighter to the observer¹⁶.

It seems that Le Corbusier did not distinguish between saturation and brightness of colors when making up his nuances. So that *blackness* and *chromaticness* values are the direct consequence of adding different proportions of white to the *main color* of each family, this is, to the darkest and most saturated representative color for each hue family.

Chromaticness characteristics of the colors

In general, colors belonging to the first Salubra collection have low chromaticness and, therefore, are little bright (fig 5). The highest value of chromaticness is 60 and it corresponds to the 090 Vermilion-red and to the 080 orange, and are followed by the *main colors* for carmine, green and ultramarine families, with chromaticness of 40 (020, 051, 081, 101). Only 12 colors have a chromaticness placed between 40 and 60. The other colors (29), have a chromaticness equal to or lower than 30, and

[†] In the color palette for the *Maison du Pelerin* in Ronchamp (FLC 01-7), two *cadmium yellow* shades are shown, together with a *blue ultramarine* and a *gray* color that have nothing to do with the scarcity of *yellow* shades in Salubra I.

they include the *main colors* of sienna, earth and brown families, as well as the ranges of gray shades which have a chromaticness value equal to 0.

Figure 6

If we study the two colors with highest saturation, we can notice that the 090 Vermilion is very recurrent in the most part of *claviers*, being only absent in three of them (Velvet I, Wall I and Sand I), while the 080 orange is used only in three cases (Velvet II, Sand II and Variegated III). The other orange colors, 081 and 082, have even a minor role, since they only appear in Velvet II accompanying the 080. So, the ranges of warm colors in the *claviers* are formed using carmine (100) and Vermilion (090) as the outstanding colors, that is, as the most saturated colors, and avoiding the oranges. In the case of cool ranges, the most saturated colors are green (051) and ultramarine (020), but the recurrence of one over the other is not significant.

CRITERIA OF HARMONY IN THE COMBINATIONS OF COLORS IN THE SALUBRA COLLECTION FROM 1931

Harmonies based on the hue similarity

We have represented in a graph all color combinations, taking colors in pairs from the 12 Salubra *claviers*. In the abscissa and ordinate axis, we have located the 43 available colors, organized in the 12 hue families. We have made circles of different diameters, with a number indicating how many times each color combination appears in the whole of the charts (Fig. 7), giving an idea of the recurrence of each pair of colors. The pairs formed by two colors from the *valeurs de fond*, are represented separately and considered apart from the remaining combinations, as they are far more numerous. In the graph we mark with a striped gray the geometric place for those combinations with the same NCS hue family.

Figure 7

If we observe the combinations based on the similarity of hue, looking at this graph, it is evident that a large number of them are in the area close to the diagonal, that is, most of these combinations happen between colors that belong to the same hue family. This is so especially in those pairs formed by two *color tons*. When a *color ton* and a *valeur de fond* take part, the dispersion is slightly higher. So we can state that the first criterion of harmony for Le Corbusier is to combine colors with similar hue or belonging to the same hue family, especially in the pairs of *color tons*.

It is interesting to observe certain combinations between hue families that are little recurrent or nonexistent. Thus, among the blue colors, those belonging to the ultramarine family are almost never combined with the cobalt blues, and exceptionally a blue with a green. It is not usual either the combination of blue colors with orange and carmine colors, using instead the Vermilion-red nuances, or other color hues, such as ochre, Sienna and other neutral shades.

In the case of green colors, we can observe combinations between two hue families, the *Veronese green*, which is more bluish, and the *yellowish green*, and of course the pairs of green colors belonging both to the same hue family. The combinations of green colors with sienna, ochre, red and carmine, and exceptionally with shadows or brown, are also frequent. In addition, ranges of yellowish green seem to be preferred against Veronese green, although this is largely due to the fact of having selected three yellowish green hues as *valeurs de fonds* in the 'Landscape' keyboard. If we pay only attention to the pairs consisting of two *color tons*, there is no combination between the yellowish green hues and vermilion-red or orange hues. It seems that together with the warm green colors (yellowish greens), it is chosen the carmine, which is a cooler red, and not Vermilion: a preference for a subtle warm- cool contrast enhancement.

The colors of the orange family are combined together, and with carmine, ochre, some gray colors, ultramarine blue and Veronese green, but always between nuances with little *blackness*. We have already stated above, the little recurrence of these ranges of orange colors, compared to the much more important role for the Vermilion-red and carmine colors, both as a counterpoint to the cool ranges.

It is noted that the colors of the red families are the most versatile, as they are combined with nuances of all other hue families, and there is more presence of Vermilion-red colors than carmine ones. Carmine color, which is more bluish, is reserved as a counterpoint to the orange and the yellowish-green, which is warmer than the Veronese: again a preference for a subtle warm- cool contrast enhancement.

1
2
3 For the other families of earthy hues (ochres, Siennas, brown and shadows), the most frequent
4 combinations, as in previous cases, happen between colors of the same hue family, except in the case of
5 the numerous *claviers* where they are used as *valeurs de fond*. Ochre and Sienna are combined with all
6 other hue families, and to a much lesser extent, with carmine and orange hues. For example, we never
7 observe a combination of sienna with orange. *Shades* and brown hues are also combined with all the rest
8 of the hue families, being more exceptional the pairs of green and orange colors.

9 We can conclude that harmonies based on the similarity of hue are common in the first Salubra
10 charts, especially if we consider the pairs of two *color tons*. And this is especially significant for the
11 orange, Veronese green and even carmine hue families, for which it seems to be the most preferred color
12 harmony criterion. On the contrary, as a counterpoint to the Vermilion-red and orange colors, a cool green
13 (Veronese green) is preferred, and as a counterpoint to the carmine-red colors, which are cooler than
14 Vermilion, the yellowish greens or oranges are preferred.

15 Harmonies based on the hue contrast

16
17 One possible criterion of harmony lies in the use of colors that are opposite in the color wheel
18 and, therefore, complementary colors. Chevreul, Goethe, Munsell or Itten, studied this principle of
19 harmony that had great influence on the Impressionists and Post-Impressionist painters, like Signac or
20 Seurat.

21 Le Corbusier certainly should be aware of these principles of color complementarity, but his
22 Salubra charts are not made up with an ordered system of colors where we can observe the existence of
23 opposite or complementary colors, such as it is evident in the construction of the NCS color space. NCS
24 color space is organized considering pairs of opposing colors: red-green, blue-yellow, black-white.

25 Le Corbusier's colors and combinations seem not to be selected by searching a strict opposition
26 between complementary colors. If we project the Salubra colors and combinations on a two-dimensional
27 plane, just a few lines cross the figure exactly through the center of the color wheel (fig 3). The
28 connection between the Salubra colors draw a figure with a similar geometry to triangles, with a series of
29 vertexes linked with the *main color* of each hue family, those colors that are the most chromatic and dark.

30 In other words, it seems that there exist a criterion of harmony that seeks the balance between
31 cool and warm colors, rather than a strict or scientific criterion of complementarity. This must not
32 surprise us, since Le Corbusier himself states that "*the classification into two large categories of warm*
33 *tones and cold tones brings order: every color (tone & value) heads either towards the light side*
34 *(warmth, gaiety, joy, violence), or towards the shadow side (freshness, serenity, melancholy, sadness)*"¹².
35 Heer⁶ claims that blue and red constitute the basic pair of colors for Le Corbusier's, and they symbolize a
36 contrast which goes beyond the pure optics and reaches psychological, associative and architectural
37 issues. "*Red (and its brown, orange, etc... combinations) fixes the wall, affirms its exact position, its*
38 *dimension, its presence. Moreover, to blue are attached subjective sensations, of softness, calm, of water-*
39 *landscape, sea or sky. To red are attached sensations of force, of violence. Blue acts on the body as a*
40 *calmative, red as a stimulant. One is at rest, the other is action*"¹². Moreover, it should be noted that this
41 duality between two opposite colors, red-blue, in terms of light-shadow, warmth-freshness, happiness-
42 serenity, joy-melancholy, violence-sadness, is a literal translation of Goethe's¹⁷ theory of color and his
43 pair of opposite colors, yellow-blue, to which he assigned the qualities of distance-proximity, power-
44 softness, repulsion-attraction, and others. Le Corbusier simply replaces the yellow of Goethe's outline by
45 the red.

46 The balance between cool and warm colors explains properly the criteria of harmony for many of
47 the existing combinations in the first Salubra collection. In Figure 7, we can observe in a striped area, the
48 geometric place of the combination with opponent cool-warm color pairs, and we find a large number of
49 samples in it. We have considered as cool colors the hue families of ultramarine blue, cobalt blue,
50 yellowish green and Veronese green; and as warm colors, the hue families of orange, Vermilion-red, and
51 carmine. We do not include ochre, sienna and brown among the warm colors because, although they may
52 have a significant proportion of red, they have low chromaticness. Any of these colors combined with a
53 cool shade would be more notable by its contrast in blackness or chromaticness, than by its hue contrast.
54 We consider them neutral colors, regarding the cool-warm opposition, along with gray colors.

55 In his study about Salubra charts, Colli⁵ considered the nuances of the yellowish green family as
56 warm colors, while the nuances of the carmine family were considered as cool colors. Indeed, the
57 yellowish green color is warmer than the Veronese green, and that explains why Le Corbusier prefers
58 combining it with carmine, which is cooler, and not with Vermilion-red, as noted above. This is a purely
59 visual consideration, but we have noted that the cool-warm color opposition in Le Corbusier is more
60 conceptual than colorimetric. If the red color matches with the role of "fixing the wall," and the green and

blue colors match with that of “giving space”, this description adapts to both the carmine and Vermilion in the first case, and the yellowish green and Veronese in the second.

Harmonies based on the similarity or contrast of blackness

Blackness values of first Salubra colors range from a minimum of 5 corresponding to a gray and an orange color, to a maximum of 70 corresponding to a brown color, so that the maximum contrast of chiaroscuro between two colors could be 65. In the figure 8, it is represented the blackness difference for each of the pairs of colors present in the claviers.

Figure 8

In addition, we have developed a detailed study about the contrasts of blackness for the pairs of two *color tons*. In Figure 9, we observe the difference in the values of blackness of each pair of colors (ΔB) in the abscissa axis, and the value of the blackness as a percentage (B) in the ordinate axis. In the upper left part of the figure, we see the brightest colors with an equal blackness. The further to the right we look, the pairs with a higher difference of blackness we see, and the lower, the darker the combinations are.

Figure 9

We observe that most of the Salubra pairs respect a criterion of harmony based on the contrast of chiaroscuro, having only 40% of the combinations an equal blackness ΔB [0, 15], while 51% have a high contrast of blackness ΔB [20, 40], and 9% very high ΔB [45, 60]. So we can say that the contrast of chiaroscuro between both colors is a criterion of harmony used by Le Corbusier.

The combination of colors with similar blackness can be organized, likewise, into three groups. 1) Pairs of colors with *high shades*, where the blackness of both colors is B [0, 30] and which are 41% of the total. 2) Pairs of colors with *mid shades*, where the blackness of both colors is B [30, 50] and which are 6% of the total. 3) Pairs of colors with *low shades*, where the blackness of both is B [50, 70] and which are 0.5% of the total.

It is not surprising this result, since Le Corbusier believed that the visualization of architectural forms and its sculptural nature were expressed precisely thanks to the modeling of the chiaroscuro. In the arrangement of the purist form, the chiaroscuro has priority over the color. We should neither forget that the colors of the *claviers* are intended to be part of an architecture that is assumed white, and to which it corresponds, therefore, 0 as the value for blackness. Over this background, hardly all combinations of colors are perceived as contrasting, regarding the level of chiaroscuro, being those with *high ranges* only 40% of the total.

Harmonies based on the similarity or the contrast of chromaticness

Chromaticness ranges from a minimum value of 0 corresponding to the gray shades, to a maximum of 60 corresponding to the orange colors, so that the maximum possible contrast of chromaticness is 60. In Figure 10 we observe the difference of chromaticness for each of Salubra color pairs.

Figure 10

In addition, we have developed a detailed study of the contrasts of chromaticness for the pairs of two *color tons*. In Figure 11, we can observe, in the abscissa axis, the difference in chromaticness value of each pair of colors (ΔC), and in the ordinate axis, the value of chromaticness expressed as percentage (C). So that, in the top left part of the figure, we see the color pairs with lower chromaticness and equal chromaticness value for both colors in the pair. The further to the right we look, the pairs with more difference in chromaticness we find, and the lower we look, the more saturated colors we find.

Figure 11

We note that most of the pairs of *color tons* respect a criterion of harmony based on the similarity of chromaticness between both colors. A total of 68% have a chromaticness difference ΔC [0,

15] and only 10% have $\Delta C \geq 40\%$. So we can say that the similarity in the saturation between colors is a criterion of harmony used by Le Corbusier.

Pairs with similar chromaticity can likewise be arranged into three groups. 1) Pairs of *dull colors*, where the chromaticness of both is C [0, 30] and which represent 61% of the total. 2) Pairs of colors with *middle saturation*, where the chromaticness of both is C [30, 50] and which represent 12% of the total. 3) Pairs of *brightly colors* where the chromaticness of both is C [50, 60] and which represent 2% of the total.

So, regarding the colors chromaticness, Le Corbusier prefers the pairs of dull colors (with low chromaticness) and which are not opponent (similar chromaticness).

Simultaneous study about the cool-warm and the chiaroscuro contrast

In Figure 12, the color *tons* of the 12 *claviers* are represented, showing in each one of them the value of blackness and if they belong to the *cool*, *warm* or *neutral hues*, as we have mentioned above. The purpose is to observe the inflection points in the values of blackness, as well as the transitions between warm and cool colors. As if it were a sort of harmony line, we can note the presence of patterns, symmetries or gaps, considering as well the *valeurs de fond*, which give an idea of the general 'atmosphere' of the composition.

Figure 12

We note that when a *main color* is introduced, it usually is accompanied by others of the same tonal family, drawing ascending or descending lines of two or three colors regarding the chiaroscuro. It is common, for example, the sequence of sienna shades 120-121-122- 123, or shadow and gray shades 140-141-142-001-013-011-010.

When we read them in a continuous way, these pieces draw graphs with peaks and valleys which sometimes are symmetrical, as it occurs in 'Space', 'Sky' and 'Velvet I', and other times are perfectly ruled, as in 'Velvet II'. In 'Variegated III', it is remarkable the similarity of blackness of a series of colors that belong to different hue families which draw an approximately horizontal line: 091-001-034-102-021-080.

We also note that the Vermilion-red color (090) often serves to resolve the transition between difficult ranges or, as seen above, between those color pairs which are not preferred: it stands between the cobalt blue and ultramarine blue in 'Sand II', as well as between the Sienna and the carmine in 'Landscape'. Also in 'Variegated III', it stands between the cobalt blues and Sienna colors.

It is remarkable the scarcity of green and blue colors in *claviers* such as 'Variegated III', as well as among the *color tons* of those *claviers* where the *valeurs de fond* are cool colors, such as in 'Space', 'Sky', and 'Variegated I, II, III'.

OTHER COMPOSITIVE CRITERIA TO PROVIDE COLOR IN THE ARCHITECTURE OF LE CORBUSIER

We have developed a study about the criteria of color harmony used by Le Corbusier in his first Salubra charts, regarding the hue, blackness and chromaticness, but the truth is that there is still a gap between the selected colors and the way they must be applied in architecture. In his writings, Le Corbusier does not clearly show this issue, although it is possible to deduce some compositional criteria that seem to be respected. A comprehensive study in this regard exceeds our investigation, but we want to point out some general criteria for the composition of colors in the architecture of Le Corbusier.

First we must insist on a key aspect, although it may seem obvious, and it is the desire to limit the colors used in the buildings to just a small palette that is 'truly architectural'. Le Corbusier wants to prevent the use of certain inadequate colors. In addition, these colors must be arranged with moderation, as polychromy is always understood in a white color architectural context.

We have pointed out the fact that the maximum number of colors to be selected in Salubra *claviers* with the white cardboards is four. If we consider a six-sided prism as the elemental space which constitutes the Purist architecture, what Le Corbusier is implicitly pointing out is that at least two of these faces are assumed white and up to four colored (1/3 white and 2/3 in other colors). Heer argues that the Salubra colors were primarily intended for the four walls of a room, while the ceilings used to be white. That is, at least, what Le Corbusier indicates in projects such as *Villa Baizeau* (1928) or *Centrosoyus* (1928). Nevertheless, it is noteworthy that the cardboard area assigned to isolate the *valeur de fond* is twice as large as the one for the *color ton* (2/3 background color and 1/3 *color ton*). Ruegg points to the

possibility that the *color ton* was reserved for secondary elements of the composition, and therefore it should be in smaller proportion than the *valeurs de fond*, but Le Corbusier does not talk about this issue at all. We just have found a short note describing the paint for the *Maison du Brésil* (1958), where it is indicated a proportion of 1/2 for white and 1/2 for polychromy, in which a maximum of 15% should be for bright colors. This ratio cannot be considered immovable, as it is explained in the same text that the final proportion should be evaluated on site by Le Corbusier himself[‡]. So we can conclude that white is assumed to be in a proportion corresponding from 33% to 50% or more of the surfaces, while polychromy should be limited to a maximum between 50% and 66% of the surfaces. Furthermore, the more vivid colors or color *tons* should be limited to a ratio between 7.5% and 22%.

It is important to insist that one of the fundamental principles that govern Le Corbusier's polychromy is his desire to submit architecture to an accurate compositional order, so that the colors show a hierarchy in the interpretation of the different pure volumes that make up a building and help in the reading of architecture. Whereas the "blue is space and the red is fixing the space", we can understand many chromatic operations which are carried out to increase the spatial perception, limit the dimensions of the geometry, separate one volume from another, correct dimensional errors, etc.

We should not forget either the symbolic connotation that Le Corbusier matches to color, that is, the ability of linking ideas, so that the green may represent nature, the red a wall, or the blue the sky. This capacity of linking explains the presence of red colors on walls, which he want to act as a limit to the perception of a space, and also the presence of green colors in the vegetal roofs of some villas, as well as in the ground floor of the *Villa Savoye* (1931) which camouflages with the vegetal background, or in the medians of the gardens of the Housing in Pèssac, to name a few.

The use of *plain colors* and the renunciation of the color gradients that could alter the two-dimensional character of the planes that make up the architecture, can also be established as a basic compositional criterion. Despite the ability of color of moving forward or backward, Le Corbusier did not want to break the spatial box, but to introduce some tension in the *rectangle élastique*, following the term coined by Fernand Leger and rightly pointed out by Rüegg. This fact differentiates Le Corbusier from the polychromy of *De Stijl*.

It is also usual that colors cover the entire surface of the architectonic element: wall, ceiling, etc. In the exceptional cases where this does not happen, the colors are finished in a coherent way with other compositional aspects of the architecture. Heer notes Le Corbusier's preference for arranging the blue colors in the darker areas of the buildings and the red colors in the lighted ones. And all these colors on surfaces are set after considering the visuals that Le Corbusier finds along the *promenade architecturale*, when he walks around the building during the construction phase, and he ends up specifying colors by following his own intuition. The harmony of colors is not perfectly defined in the conception phase, but it is settled at the end, on-site.

CONCLUSIONS

We have carried out a new study of the color combinations selected by Le Corbusier in the *claviers* for the Salubra wallpaper company in 1931, by analyzing them in the color space of the Natural Color System (NCS), which allows us to understand the perceptive variables of colors (hue, blackness and chromaticness) as well as their harmony criteria.

Regarding the hue families, we have observed that the 43 colors are derived from 12 main colors, which are mixed with white in different proportions to obtain all the nuances. Beyond the 9 gray and neutral colors, half of the remaining colors belong to cool hues (R10B to Y80R) and half to warm colors (G40Y to R80B). We note the difference of these brownish colors with low saturation, with those typical of the traditional architecture, despite Le Corbusier's desire of linking them with the "eternal colors".

To complete the color wheel, we would still need colors from the yellow (Y60R to G40Y) and violet (R80B to Y10B) hue ranges. Neither white color appears, as it is presupposed for architecture, nor

[‡] "Monsieur Le Corbusier déterminant lui même sur place la distribution des différentes couleurs et ceci au moment ou l'entrepreneur devra commencer les travaux, il est donc impossible de définir à l'avance avec précision l'emploi des couleurs.

Il convient que l'entrepreneur évalue à 50% la partie en blanc et à 50% la partie peinte en couleur, dont 15% de teintes vives.

Ces évaluations n'engagent pas l'entrepreneur, les quantités réelles seront seules prises en compte au moment du règlement du marché." (FLC 408, CUB-Doc F Pe -5)

black. Some of these absences are covered in the second Salubra collection from 1959, and in the buildings constructed after the Second World War.

In general, colors from the first Salubra collection have low chromaticness ($C \leq 60$) and low blackness ($B \leq 70$). The highest value of chromaticness corresponds to the 090 Vermilion and 080 orange; while the highest value of blackness corresponds to the 130 brown. The lightest color is the 001 ochre.

In relation to the harmony criteria, it is shown that color harmonies based on the similarity of hue are common, especially if we consider the pairs of two *color tons*. And this is especially significant for the orange, Veronese green and even carmine hue families, for which it seems to be the most preferred color harmony criterion.

There are also many color pairs whose harmony is based on the contrast of hue, not between complementary and opposite colors in the color wheel, but between cool and warm colors. This opposition was reported by Le Corbusier himself and it explains many of the combinations in the first Salubra collection. Blue and red are considered antonyms in a visual, psychological, symbolic and architectural level.

If we study the harmonies based on the similarity or the contrast of chromaticness, we notice that Le Corbusier prefers the pairs of *dull colors* (with low chromaticness), and with little contrast between them (same chromaticness).

Regarding the blackness, most of the Salubra combinations respect an harmony criterion based on the contrast of chiaroscuro, with special dominance of *high shades* of colors, this is, pairs of colors with low blackness. This is especially significant in the combinations of two *color tons*.

In a comparative study about the cool-warm and the chiaroscuro contrast, the presence of rhythms and patterns in the *claviers* is demonstrated, because a *main color* is usually accompanied by other nuances from the same hue family. Moreover, we can note that the Vermilion-red is used to resolve the transition between the conflicting ranges or those color combinations which are not preferred.

Finally we can point out other compositional criteria to provide color in the architecture of Le Corbusier: 1) The architect limits the palette to 43 colors and the white, which is assumed as a background in a minimum ratio between 33% and 50%, while the brightly colors should be limited to a ratio between 7.5% and 22%; 2) The colors has to help the understanding of the different pure volumes that make up a building and its hierarchy; 3) The architectural color is often explained by its associative connotations; 4) Plain colors are used and the color gradients are rejected; 5) and the colors usually cover the entire surface of the architectonic element to be colored, except in some few cases.

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CAPTIONS

Figure 1. 3D-Virtual model with all Salubra pairs of colors in the NCS color space.

Figure 2. Color ranges pointed out by Le Corbusier in different texts.

Figure 3. All Salubra pairs of colors plotted in the NCS color circle.

Figure 4. Colors sorted by the times that they appears in the 312 combinations of four colors.

Figure 5. NCS blackness for each Salubra color.

Figure 6. NCS chromaticness for each Salubra color.

Figure 7. All Salubra pairs of colors, showing the number of combinations, and the geometric space for the same NCS hue pairs and the complementary pairs of colors.

Figure 8. All Salubra pairs of colors, showing the difference of blackness among them.

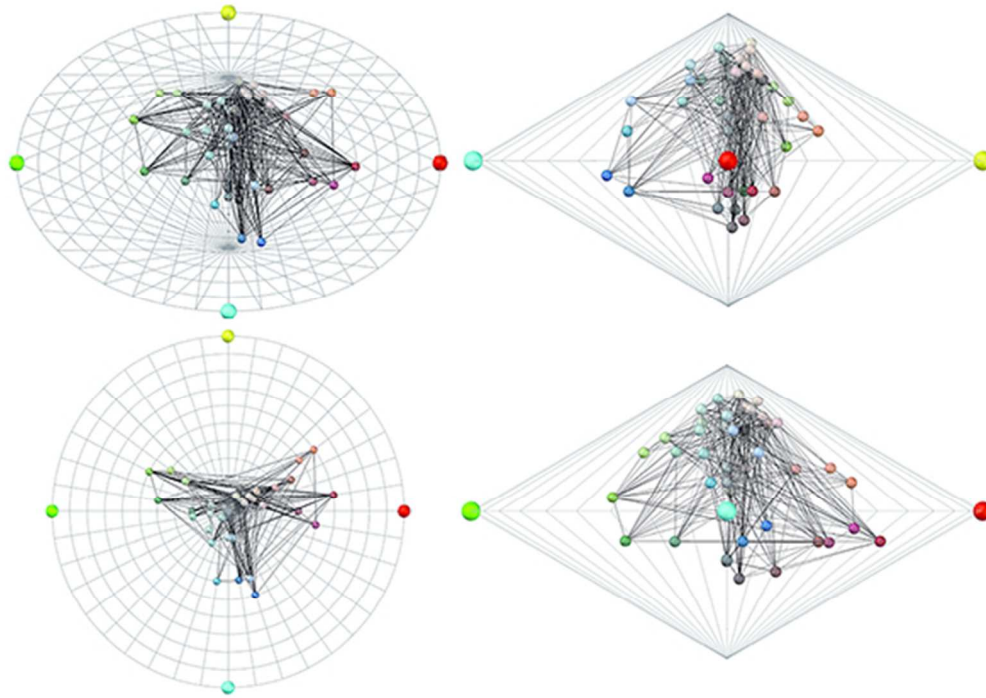
Figure 9. Connection between the difference in NCS blackness and the medium blackness for all pairs of two *tons* color.

Figure 10. All Salubra pairs of colors, showing the chromaticness difference between them.

Figure 11. Connection between the difference in NCS chromaticness and the medium chromaticness for all pairs of two *tons* color.

Figure 12. NCS blackness and color temperature for every *ton* in each keyboard.

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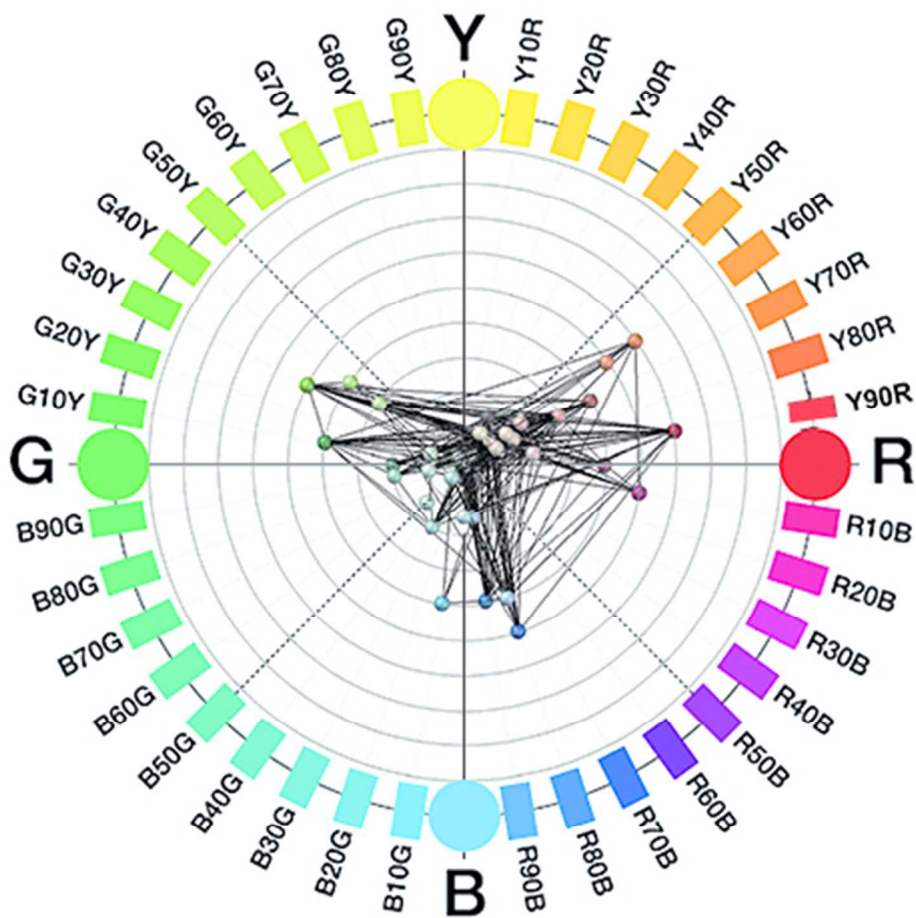


3D-Virtual model with all Salubra pairs of colors in the NCS color space.
50x35mm (300 x 300 DPI)

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<i>Le Purisme</i> (1918)			<i>Noble range</i> (1932)	<i>Salubra I</i> (1932)	<i>Coloures Types</i> (1951)	<i>Salubra II</i> (1959)
<i>Large Gamma</i>	<i>Dynamic Gamma</i>	<i>Transition Gamma</i>				
yellow			yellow		yellow	
	lemon-yell.					
Earthy colors				Yell. ochre	ochre	Yell. ochre
			Sienna	Sienna	Sienna	Sienna
				Brown		Brown
			Bunt sienna	shades	shades	shades
	Orange chr			Orange	Orange	
	Orange cadm					
Red ochre			Red ochre	Red ochre		
			vermillion	vermillion	red	vermillion
			Carmine	Carmine		
			English red			English red
					Violet	
Ultramar			Ultramar	Ultramar	Ultramar	Ultramar
		Cobalt Bl.		Cobalt Bl.		
			Blue		Blue	Blue
		Emmerald				
				Verones		
			Engl. Green	Yell. green	Yell. green	Yell. green
						Greenish Yell.
white			white			white
				Greys	Grey	Grey
Black			Black			

Color ranges pointed out by Le Corbusier in different texts.
56x64mm (300 x 300 DPI)

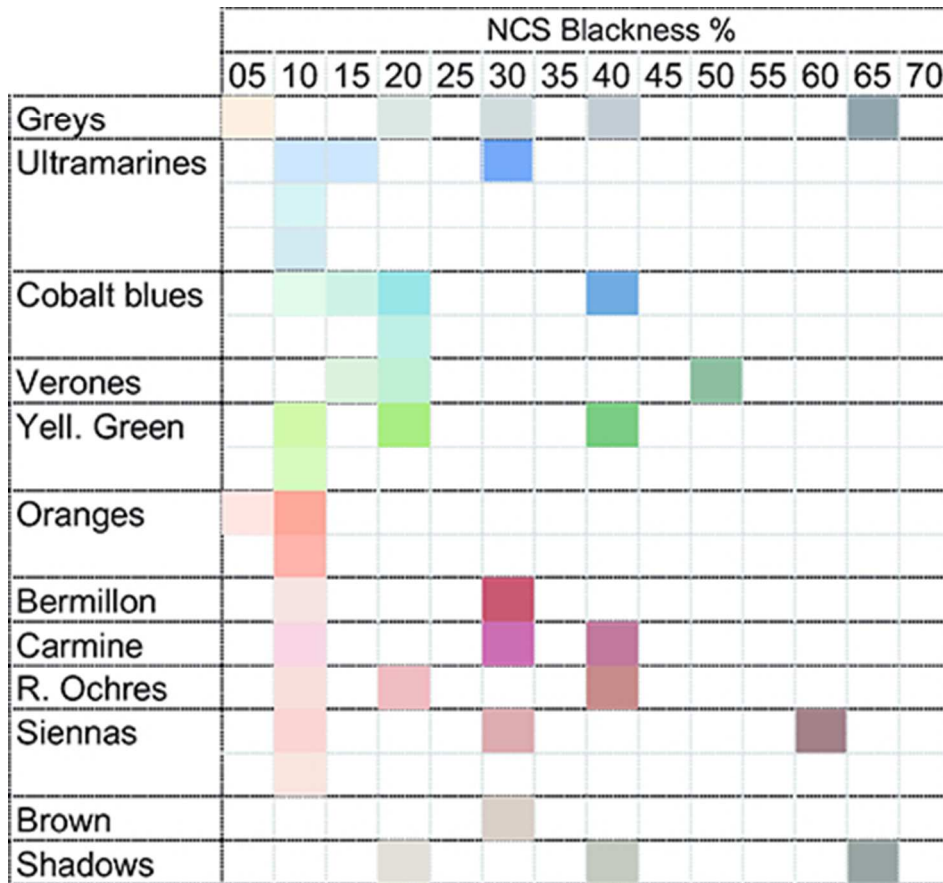


All Salubra pairs of colors plotted in the NCS color circle
39x39mm (300 x 300 DPI)



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Color Id.	NCS Notation	Number of times combined	Claviers where this is a <i>valeur de fond</i> (times combined as a <i>valeur de fond</i>)
001	5 10 Y30R	110	Velvet 1, 2 and Variegated 3 (78)
122	10 20 Y60R	80	Wall 1 y Wall 2 (52)
131	30 10 Y50R	60	Sand 1 and 2 (52)
112	10 15 Y70R	52	Wall 1 and Wall 2 (26)
091	10 10 Y70R	52	Wall 1 and Wall 2 (26)
013	20 2 G50Y	50	Velvet 1, 2 (26)
121	30 30 Y70R	43	Variegated 2 (13)
120	60 20 Y80R	43	Variegated 2 (26)
011	40 0 N	41	Variegated 1 (13)
051	20 50 G30Y	40	Landscape (26)
110	40 40 Y70R	37	Variegated 2 (13)
032	20 20 B30G	34	Sky (26)
030	40 40 R90B	34	Variegated 1 (26)
082	5 15 Y60R	30	Sand 1, 2 (26)
022	15 15 R90B	30	Space (26)
090	30 60 Y90R	27	
020	30 50 R80B	27	Variegated 3 (13)
060	05 15 Y30R	26	Sand 1, 2 (26)
012	35 0 N	26	Velvet 1, 2 (26)
130	70 5 Y80R	25	Variegated 1 (13)
053	10 30 G40Y	25	Landscape (13)
033	15 15 B50G	25	Sky (13)
024	8 4 B50G	25	Space (13)
142	20 5 Y40R	23	
140	65 2 Y	22	
010	65 2 B	22	
050	40 40 G10Y	21	Variegated 3 (13)
141	40 5 Y20R	19	
034	10 10 B90G	19	Sky (13)
100	40 40 R	18	
021	10 30 R80B	18	
052	10 40 G40Y	17	Landscape (13)
023	10 15 B	17	Space (26)
111	20 30 Y70R	14	
102	10 20 Y90R	14	
041	20 20 B90G	14	
040	50 20 G	14	
123	10 10 Y50R	12	
101	30 50 R10B	12	
042	15 10 G20Y	12	
080	10 60 Y60R	8	
081	10 50 Y60R	4	
031	20 40 B10G	4	

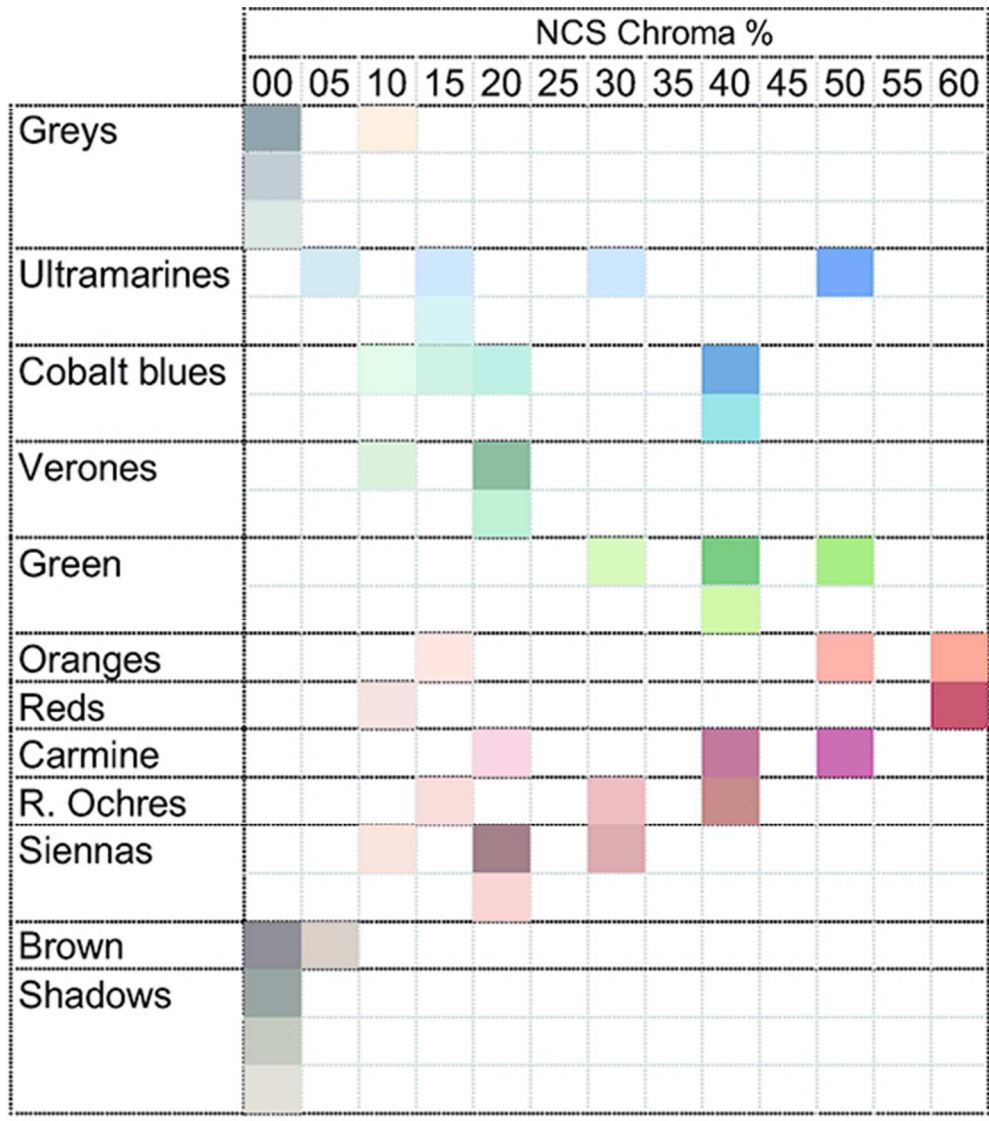


NCS blackness for each Salubra color
39x37mm (300 x 300 DPI)

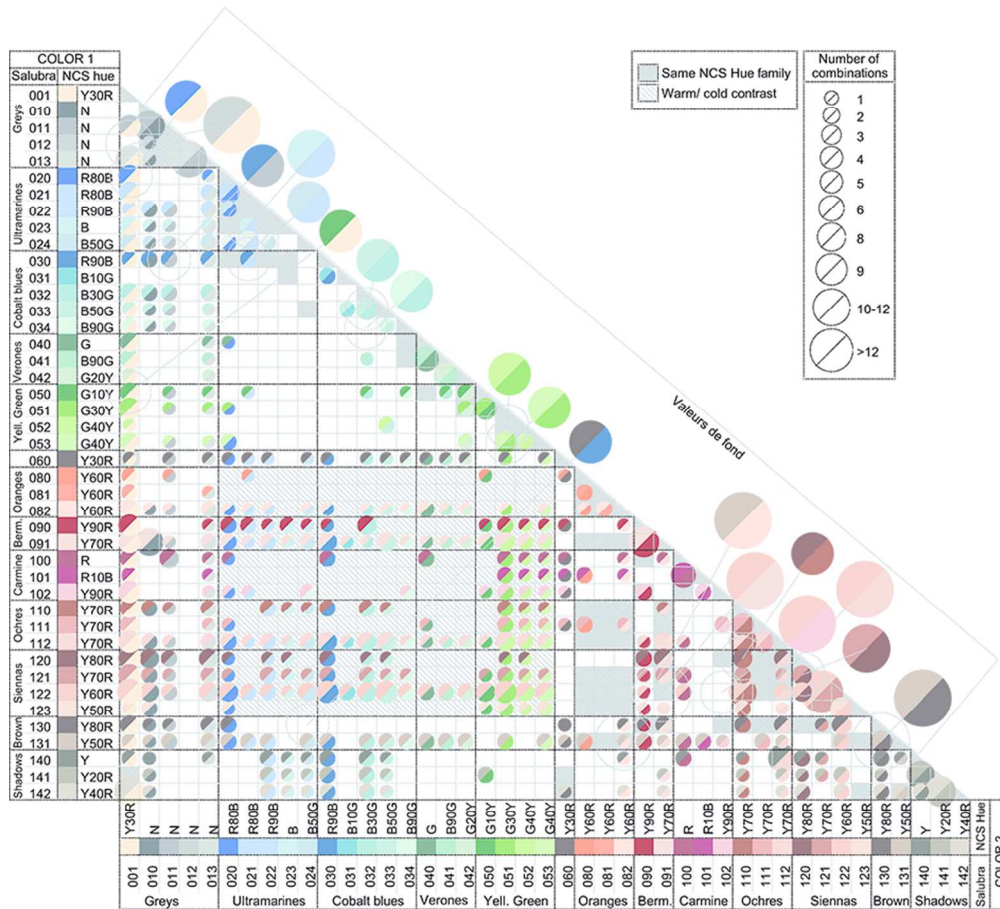
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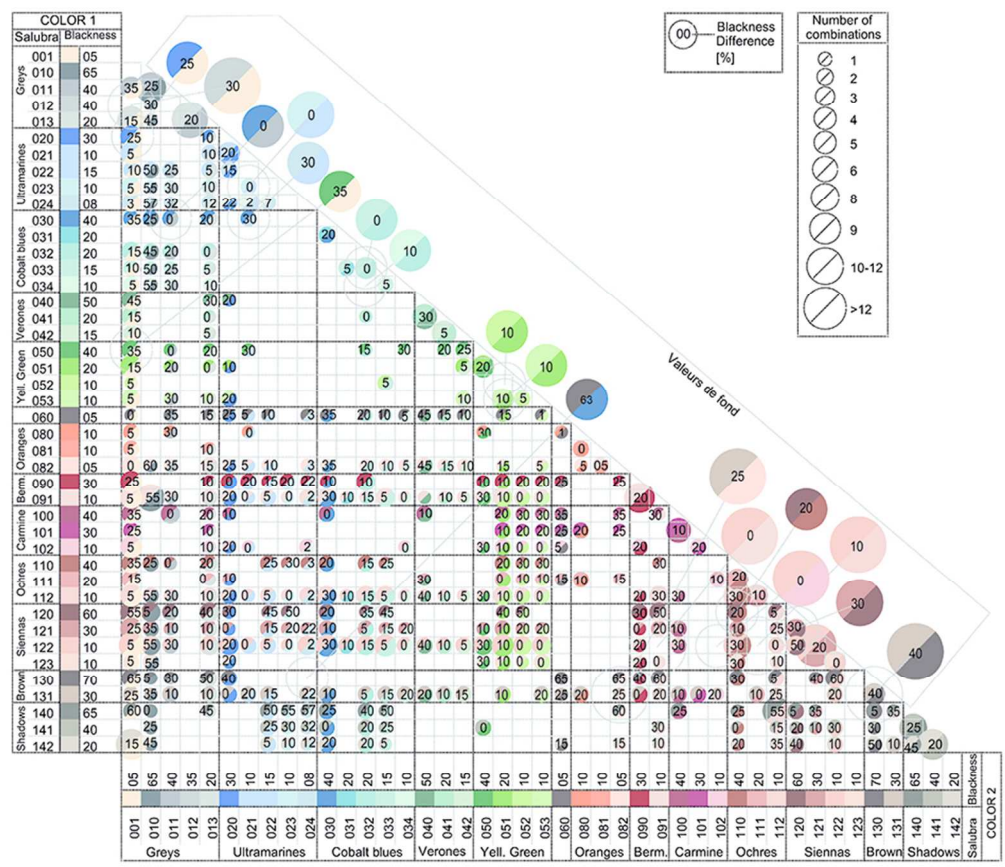


NCS chromaticness for each Salubra color.
50x56mm (300 x 300 DPI)



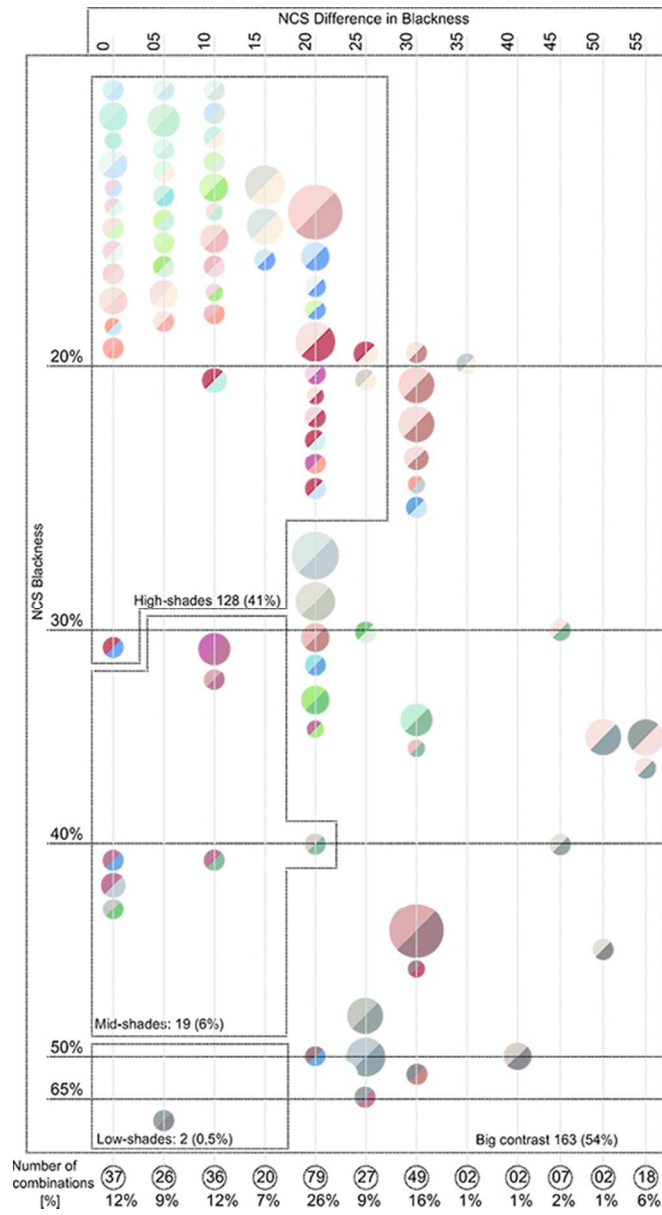
All Salubra pairs of colors, showing the number of combinations, and the geometric space for the same NCS hue pairs and the complementary pairs of colors
80x72mm (300 x 300 DPI)

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All Salubra pairs of colors, showing the difference of blackness among them.
80x68mm (300 x 300 DPI)

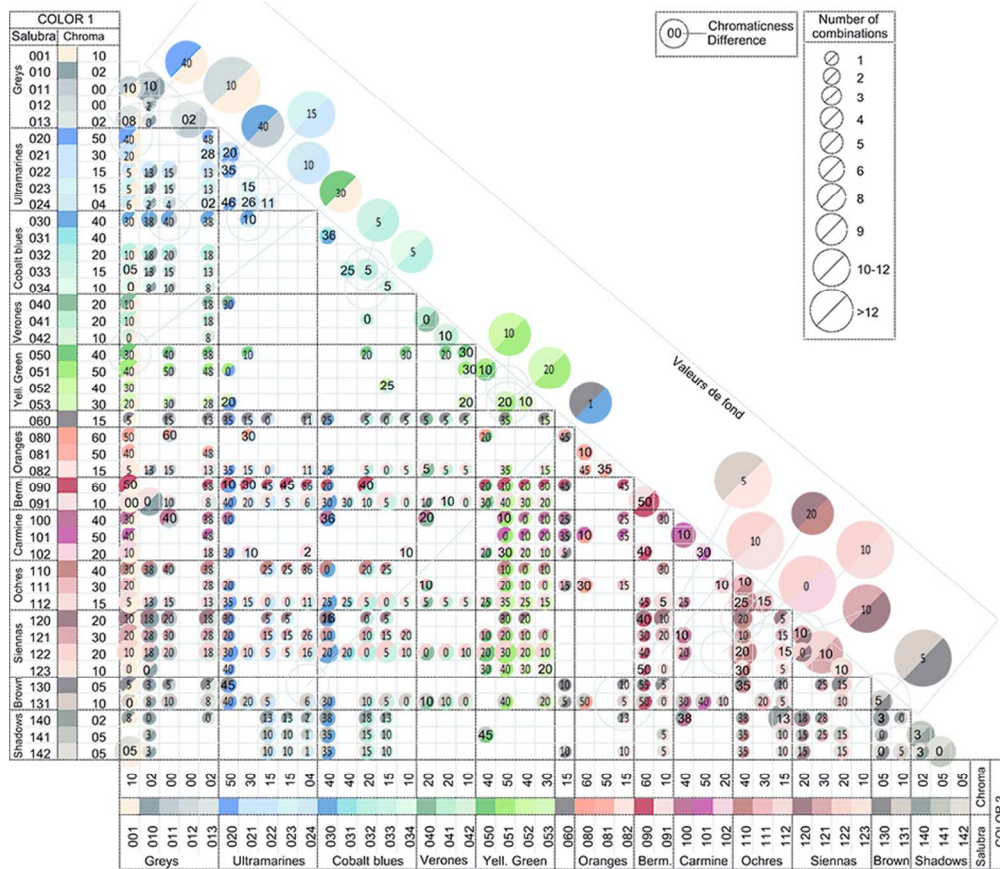
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Connection between the difference in NCS blackness and the medium blackness for all pairs of two tones color.

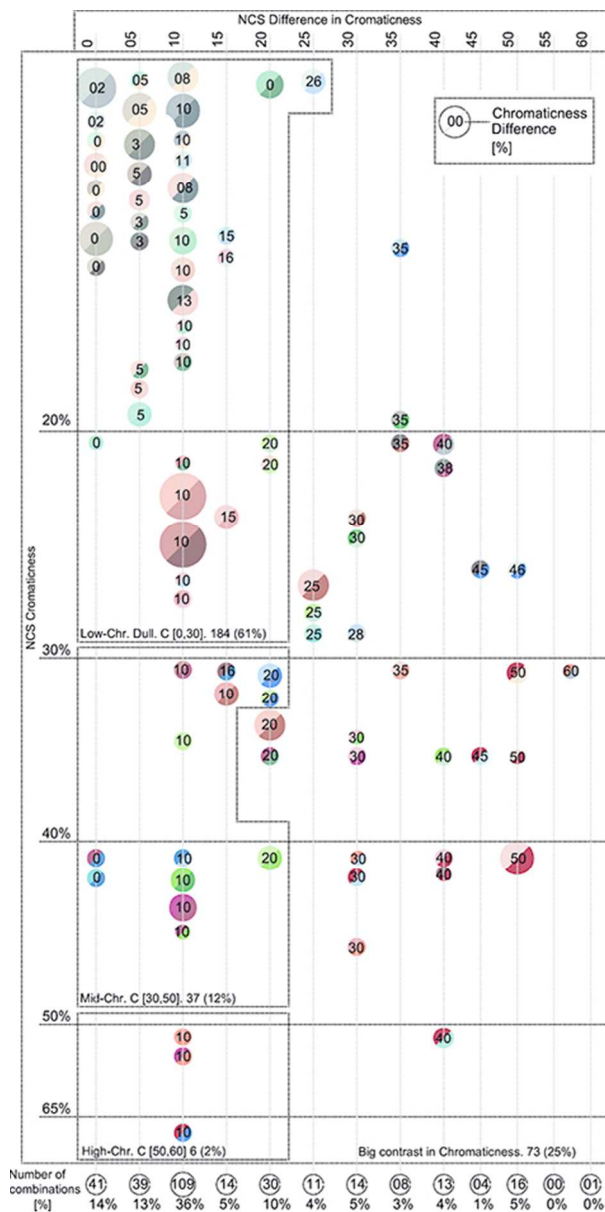
43x80mm (300 x 300 DPI)

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All Salubra pairs of colors, showing the chromaticness difference between them. 80x69mm (300 x 300 DPI)

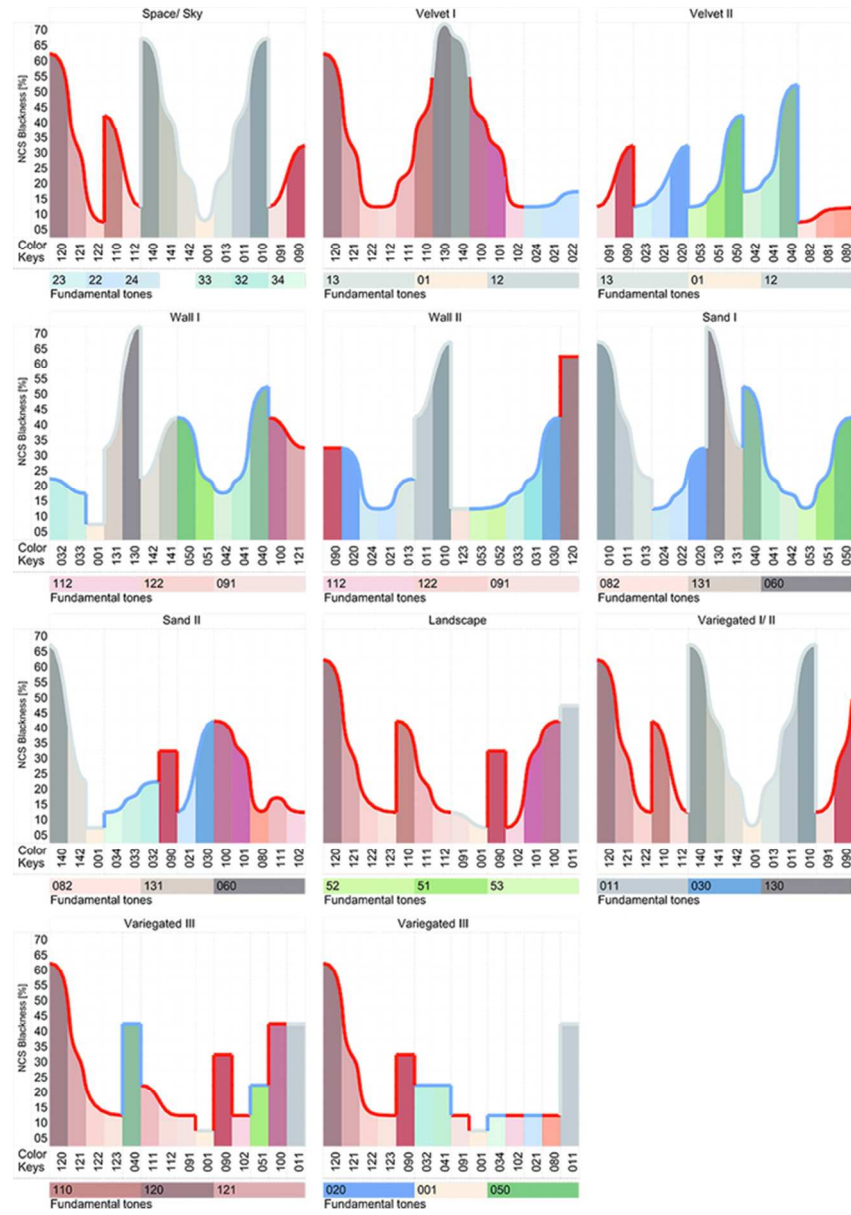
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Connection between the difference in NCS chromaticness and the medium chromaticness for all pairs of two tones color.

39x80mm (300 x 300 DPI)

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NCS blackness and color temperature for every ton in each keyboard.
57x81mm (300 x 300 DPI)