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RESEARCH ARTICLE

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Preference for accent and background colors in interior architecture in terms of similarity/contrast of natural color system attributes

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Abstract

Color combination criteria are said to entail an affective response in interior design. We investigated the color combination criteria that orient the preference of current observers, after Le Corbusier's 1931 Salubra keyboards. We explored the similarity/contrast in Natural Color System (NCS) hue, blackness, and chromaticness in 312 combinations with four colors, two backgrounds and two accent colors, coming from 43 individual colors, on the walls of a simulated interior of a bedroom from the Swiss Pavilion (Le Corbusier, 1930-1931). Participants were 644 students of architecture and interior design in Western Europe and Near East, who evaluated with a Likert scale their preference for virtual images via an online survey. Results indicate that the most preferred color combinations are those with hues closer in the color wheel, being the similarity between hues in the backgrounds more important than in the accent colors, and with NCS B30G to G as the most preferred hues. Observers preferred color compositions with blackness under 10% and similar blackness between the two background colors, together with a certain blackness contrast between these background colors and the two color accents. Similarly, observers liked color compositions with low chromaticness and low chromaticness difference among the four colors of the composition.

KEYWORDS

color harmony, color preference, interior architecture, Le Corbusier, NCS

1 | INTRODUCTION

In interior architecture, colors do not appear isolated, but rather in the form of multiple color combinations that may affect human affective response. Nevertheless, studies about the influence of color in interiors very often refer to individual colors and prioritize just hue among the three perceptual variables, to study the impact in well-being, mood, performance, etc.[1-6] On the contrary, when architects and designers face a real project, it is unusual to display a single uniform color and the interest is oriented to the affective response produced by groups of colors in harmony.[7,8] When a group of colors produces a satisfying affective response, they are said to be “harmonious,” but the term is an abstruse concept described differently by different authorities.[9-12]

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In the field of applied arts and architecture, since the beginning of the nineteenth century, there has been a considerable number of artists and theorists attempting to obtain formulas and principles to predict the relationship between color combinations and aesthetic response. Some of them were Michel-Eugène Chevreul (1839), Johannes Itten (1962), Albert H. Munsell (1921), Friedrich Wilhelm Ostwald (1916) and, more recently, Nemcsics,[13] Hard and Sivik,[14] or Ou et al[15] (see a literature review in Reference 16 [chap4]). Some of the principles of color harmony were simple formulas with the intention of explaining perceptual color order systems, but were never assessed scientifically. In fact, there is evidence that a systematic selection of colors in an order system does not necessarily lead to harmony.[17] O'Connor reviewed the multiple theories related with color harmony, indicating the epistemological differences in their initial assumptions and suggesting that color harmony is contingent on individual and cultural aesthetic factors, as well as perceptual, contextual, and temporal factors.[18] So, nowadays, we need to acknowledge that a color harmony criterion can just be a contingent assumption and not a universal categorical law, but we also need to recognize that some of the principles of color harmonies set since the nineteenth century have become usual "color combination criteria" or "rules of grammar and sintax" to orient architects and designers. Current applications keep using the principles of similarity and contrast between the three perceptual variables of color, namely hue, value, and saturation, to suggest palettes of colors useful for different purposes: Adobe Color (https://color.adobe.com/es/create/color-wheel), Coolors (https://coolors.co/), ColourLovers (https://www.colourlovers.com/), Colour Harmoniser,[12] etc. The study of the similarity/contrast of the perceptual attributes of a group of colors keeps being a useful approach to investigate how these colors orient a positive affective response, and relies on the usual way of working of professionals.

Nowadays, the assessment of any "satisfying affective response" necessarily implies an experiment with observers to record objective indicators, and with a strong statistical analysis of the results. This is the case of Nemcsics, who has developed experimental determinations of laws of color harmony for more than 50 years, setting a particular model known as the Coloroid color system[19] and with a transfer of these harmony findings evaluated in two-dimensional abstract collages into architecture by means of a "color-dynamic planning method."[20] It is important to point out that the difference between color preference and color harmony is often subtle. In literature, color preference tends to refer to a personal inclination toward an individual color that is more appealing than other, but when there is a group of colors, the overall assessment in terms of like-dislike demonstrates to be very similar to harmonious-disharmonious, being both evaluative factors or associated attributes.[7,15,21-23] For this reason, from a methodological point of view, it is possible to study the harmony of a group of colors by means of a like-dislike overall assessment.

Despite the setting of any color combination criteria, the possible color groups for architecture are infinite. A possible way to limit them is to rely on the sensitivity of an authority such as Le Corbusier, who made one of the most relevant contributions about colors combination criteria specifically for architecture, when the Swiss Salubra company commissioned him to make up some color palettes for their wallpaper collections. His contribution is noteworthy, not just for being one of the masters of the Modern Movement, but also for setting his color preferences as early as the 1930's, a period which has often been misunderstood as having just white buildings.[24] Le Corbusier selected 43 colors that he displayed in 12 different color palettes designated as "color keyboards," with an evident reference to a musical harmony.[25] Obviously, these series of harmonic colors relied on Le Corbusier's own sensitivity and color preference with the intention to orient final users in the combination of a group of colors that he considered appropriate for architecture.[26] Le Corbusier admits that the color selection relies in his own personality, but emphasizes his condition of architect:

"(I admit that in this research, the personality can sometimes appear tyrannical; about this, there is nothing I can do!) To the legitimate claim of the client that 'there is no accounting for tastes…', the architect replies 'all right, but I will keep you in the architectural plan of which I measure, more or less consciously, the realities.'" (Le Corbusier 1932)[27(p97)]

Interestingly, in his color keyboards, Le Corbusier set a difference in the extension of couples of colors that he indicated as *valeurs de fond* (background colors), which might be in a bigger proportion in the interiors, and one or two *couleurs tons* (accent colors), intended to be in a lesser extension in the interiors (Figure 2). This distinction in the extension of the different colors in interiors is important, and fits with the usual way of working of current architects and interior designers.[28,29] Experimental studies have also demonstrated that the extension of a color in an interior can be a key factor in the evaluation of the preference,[30] and different researchers have suggested that color harmony can be influenced by many factors such as shape, size, texture, the number of colors, and the relative positions of colors in a combination.[7,14,17]

In a previous research, we analyzed the different color combination criteria that were in the roots of the Salubra color keyboards, working in natural color system

(NCS). Considering that Le Corbusier set a Modulor for the dimensions of his buildings, we wanted to reveal the existence of any color combination rules in the roots of Salubra Keyboards.[31] Studying the frequency of the different color pairs, we obtained some general color combination criteria that seemed to be preferred by Le Corbusier: (a) color combinations based on the similarity of hue, particularly in the *valeurs de fond* belonging to Oranges, Veronese greens, and Carmine; (b) color combinations based on the contrast between cool and warm colors; (c) color combinations of pairs with low NCS chromaticness (pastel colors) and little contrast between them (similar chromaticness); (d) color combinations of pairs with low NCS Blackness but certain blackness contrast between them, particularly in the combinations of two *couleurs tons*. These are some of the color combination rules that oriented Le Corbusier's color preferences, but there is still a gap in the assessment of such set of color combinations in terms of preference for current observers.

The literature review confirms that an appropriate color palette is a key factor to enhance the quality of interior architecture. Architects and interior designers deal with multiple colors in different extensions for interiors, which orient different affective responses. To this goal, it is usual to use some of the traditional rules of grammar for the color combinations, regarding the similarity/contrast of the perceptual attributes of the set of colors. Architects can also follow the experience and sensitivity of other authorities such as Le Corbusier, who set his own color combinations for the buildings in the beginning of the nineteenth century. Nevertheless, it is pending an objective assessment of the validity of such color combinations for current observers. The present paper focuses on exploring the relationship between color preferences when viewed in context. In architectural design education, color theory and practice also play an important role. Therefore, the study is conducted with students from the departments of architecture and interior architecture to analyze the NCS attributes in color preferences of Le Corbusier's 1931 Salubra keyboards.

2 | OBJECTIVES

For these reasons, the main objective of our study is to investigate the color combination criteria that orient the preference of current observers for an interior design, after Le Corbusier's 1931 *Salubra Claviers*. We explore the similarity/contrast of the three perceptual variables that describe a color in NCS (hue, blackness and chromaticness) in 312 combinations with four colors, two backgrounds and two accent colors. To that aim, we choose an image of the interior of a bedroom from the Swiss Pavilion (Le Corbusier, 1930-1931) as a case study.

3 | MATERIALS AND METHODS

We translated the 43 Salubra colors into NCS, obtained all the groups of 4 colors set by Le Corbusier in the 12 Salubra Keyboards, and rendered them on a digital image of a bedroom of the Swiss Pavilion (Le Corbusier, 1930-1931), to obtain 312 bedroom images with different color combinations. A total amount of 644 participants assessed these images randomly on a Likert scale from 1—Dislike extremely to 7—Like extremely. We analyzed the impact in the preference of the similarity/contrast of the three NCS variables (hue, blackness, and chromaticness) in the group of background colors and accent colors (Figure 1).

3.1 | Case study: Stimuli

The stimuli are virtual renderings of an original bedroom from the Swiss Pavilion (1930-31), a student's residence in *Cité Internationale Universitaire* in Paris, with different color combinations. It is one of the most important buildings designed by Le Corbusier to try out his theories on collective housing and to use his philosophy “machine to live in,” in collaboration with Charlotte Perriand for the interior design.[32] Moreover, the construction of this building is contemporary to *Polychromie Architecturale* and there is evidence that Le Corbusier worked with the Salubra wallpapers for the interiors.[25] In our study, we rely on a sketch drawn and annotated by Le Corbusier available in Le Corbusier's Foundation. It is a frontal conic perspective with the observer standing in the center of the bedroom looking to the entrance, and with indications for the color distribution: the ceiling white, the floor with a gray or brown linoleum, the background colors (*valeurs de fond*) on the walls, and the accent colors (*couleurs tons*) on secondary elements. We generated a grayscale image with a 3D model using Autodesk Revit Architecture and the geometric information available in the publication *Le Corbusier Ouvre Complete*.[33] The lighting for the virtual model was set as a D65 illuminant, coming from the exterior of the building through the glass façade, thus from the back of the observer. The grayscale base image obtained was edited 312 times to incorporate all the color combinations in an underlying layer, with the software Adobe Photoshop, that assured the exactitude of the colors displayed. The color space selected was sRGB, which has a limited gamut but is the standard for a reliable web reproduction. The original Salubra colors were measured in Le Corbusier's Foundation in Paris with an NCS Colorimeter, and translated into sRGB with the NCS Navigator Tool (https://ncscolour.com/).

The color combinations for the bedrooms come from 43 individual colors selected by Le Corbusier, that he set in the 12 color keyboards *Espace*, *Ciel*, *Velour I* and *II*,

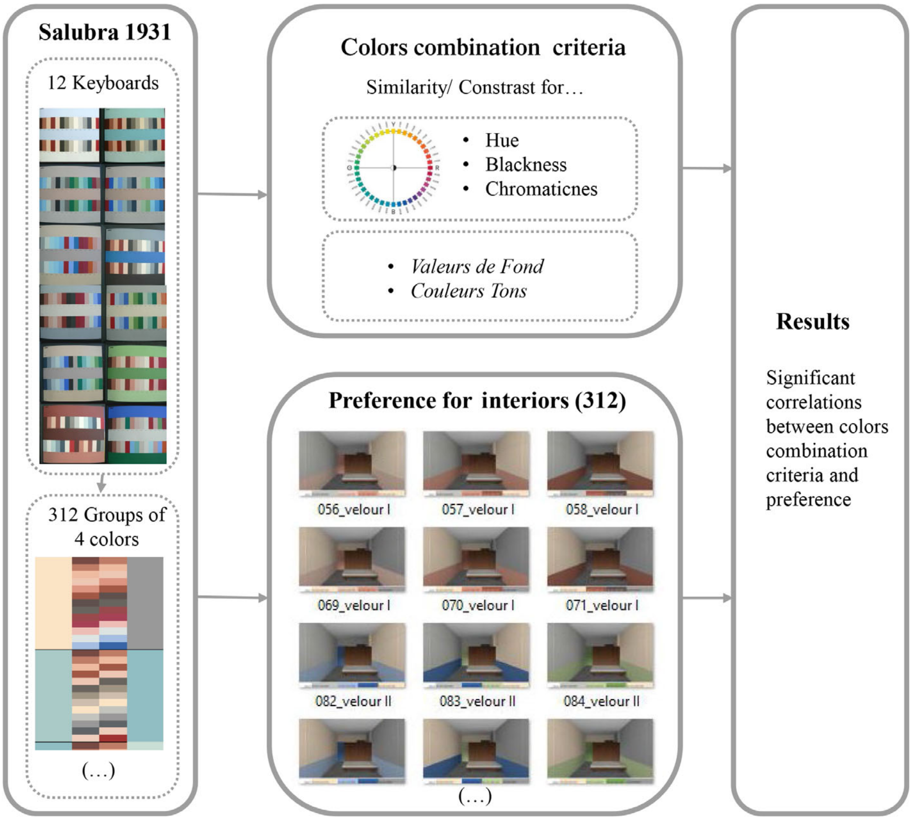

Salubra 1931
12 Keyboards
312 Groups of 4 colors
(…)
Colors combination criteria
Similarity/ Constrast for…
Hue
Blackness
Chromaticnes
Valeurs de Fond
Couleurs Tons
Preference for interiors (312)
056_velour I
057_velour I
058_velour I
069_velour I
070_velour I
071_velour I
082_velour II
083_velour II
084_velour II
(…)
Results
Significant correlations between colors combination criteria and preference

FIGURE 1 Scheme of the methodology

Mur I and *II*, *Sable I* and *II*, *Paysage; Bigarré I*, *II* and *III*. In each keyboard, the final user can isolate the colors in groups of 4, having 2 *valeurs de fond* (background colors) and 2 *couleurs tons* (accent colors) (Figure 2). The total number of possible 4 color combinations in Salubra keyboards is 312, 26 per keyboard, so this is the number of different images of the bedroom in the experiment. We labeled each image with a number that corresponds with the order of such a color combination in the Salubra Keyboards.

3.2 | Questionnaire

Participants completed the questionnaire via a website (https://lecorbusiercolors.blogs.upv.es/). Firstly, personal information was recorded with the following questions; "where are you from?," "how old are you?," "what's your gender?" Secondly, color preference was asked after this explanation: "You will be asked to assess your color preference for a bedroom from the Swiss Pavilion (Le Corbusier, 1931-1933) with 26 variations, following Le Corbusier's Salubra Color Keyboards. Please note that the scale of assessment is set as follows: 1—Dislike extremely, 2—Dislike moderately, 3—Dislike slightly, 4—Neither Like nor Dislike, 5—Like slightly, 6—Like moderately, 7—Like extremely." Then, the participant was asked to "select the color keyboard you prefer" by clicking on any of the 12 images of the Salubra Keyboards that appeared on the screen randomly. Each participant evaluated the 24 bedrooms from the selected keyboard, which appeared one after the other randomly, answering the question "I like this color combination..." on a Likert Scale.

The participants were recruited via online questionnaire sent by email to students in the School of Architecture in Universitat Politècnica de València (Spain), the Faculty of Art and Design in Kadir Has University in Istanbul (Turkey), and the School of Architecture in Mostaganem (Algeria). In each university, all the participants were enrolled in a subject related with color and interior design. Before the survey completion and during the course, students had already tested their color accuracy and possible color blindness with an online version of the Munsell Color Vision Hue Test (http://xritephoto.com/cool-tools) and the Ishihara's color vision test (http://www.dfis.ubi.pt/ ~hgil/P.V.2/Ishihara /Ishihara.24.Plate.TEST.Book.pdf). Students had also checked the color calibration of their reproduction devices, personal laptops, with specific hardware for color management (i1 Pro X-Rite). However, it was not possible to have a complete control of the lighting conditions of the room in which participants completed the survey. This is a limitation of

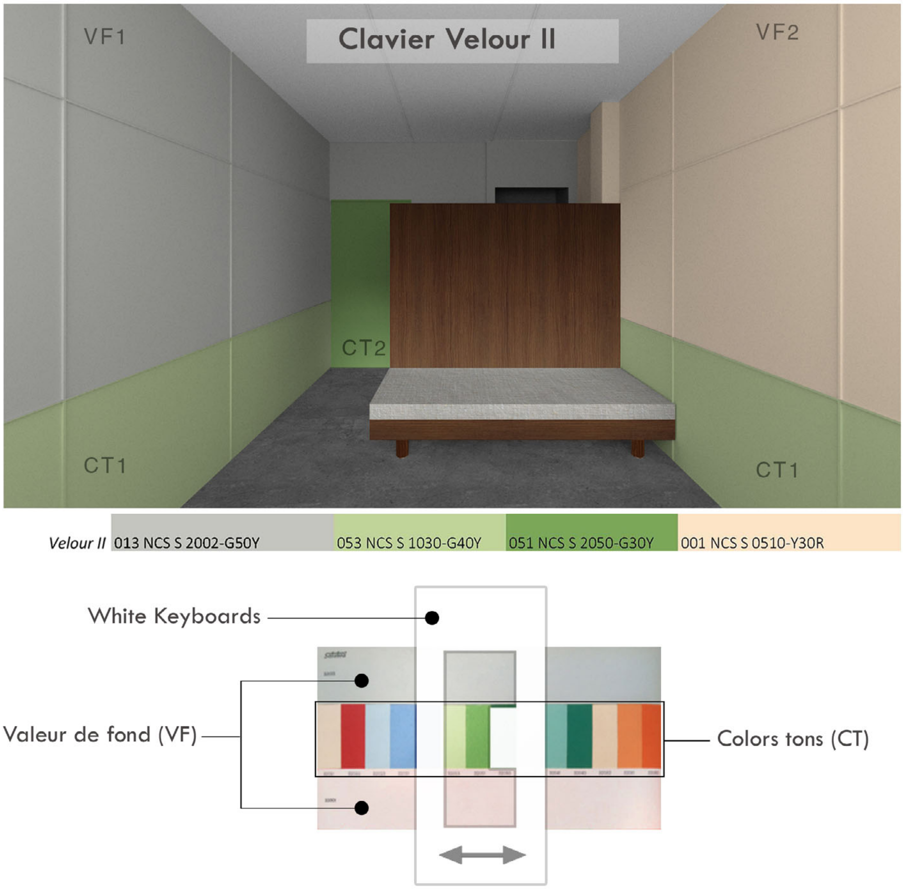


FIGURE 2 Example of a combination of four colors from the keyboard *Velour II*, applied into the virtual room. CT, *Coluleur ton*; VF, *Valeur de fond*

the study that we assumed in order that students completed the survey at their ease, particularly during the Covid-19 lockdown.

3.3 | Participants

The sample included 644 participants (388 females, 60.2%; 256 males, 39.8%) from various countries in Western Europe and Near East (250 WE, 38.8%; 394 NE, 61.1%), aged between 18 and 25 years old (mean = 20.5). In the group of Western Europe, the countries of origin were: Spain (214, 33.75%), Italy (15, 2.37%), Poland (13, 2.05%), Belgium (5, 0.63%), and Portugal (3, 0.47%). In the group of Near East, the countries of origin were: Turkey (327, 50.16%), Algeria (56, 8.83%), Bulgaria (3, 0.47%), Morocco (3, 0.47%), Siria (3, 0.47%), and Iran (2, 0.32%). The difference in the results between genders and cultures, grouped in Western Europeans and Near Easterners, was evaluated in a previous paper indicating scarce significant gender differences between males and females (5% of the bedrooms, n = 16), and scarce significant cultural differences (18.3% of the bedrooms, n = 57).[34]

3.4 | Variable description and statistical analysis

3.4.1 | Variables for the analysis of the color combination criteria

As stated before, we measured the original Salubra color papers in Le Corbusier's Foundation in Paris with an NCS Colorimeter and obtained the three perceptual variables that describe any color in NCS: hue, blackness, and chromaticness. We converted the NCS hue into a value between 0° and 351°, with 0° corresponding to Red, 90° to Yellow, 180° to Green, 270° to Blue, and 351° to R10B. NCS Blackness and Chromaticness keep the NCS values between 0% and 100%. For each of the 312 color combinations of 4 colors, we calculated the following variables: the hue, blackness, and chromaticness difference and average of the two *valeur de fond*; the hue, blackness, and chromaticness difference and average of the two *couleur tons*; and the hue, blackness, and chromaticness difference between average *couleurs tons* and average *valeurs de fond* (Figure 3).

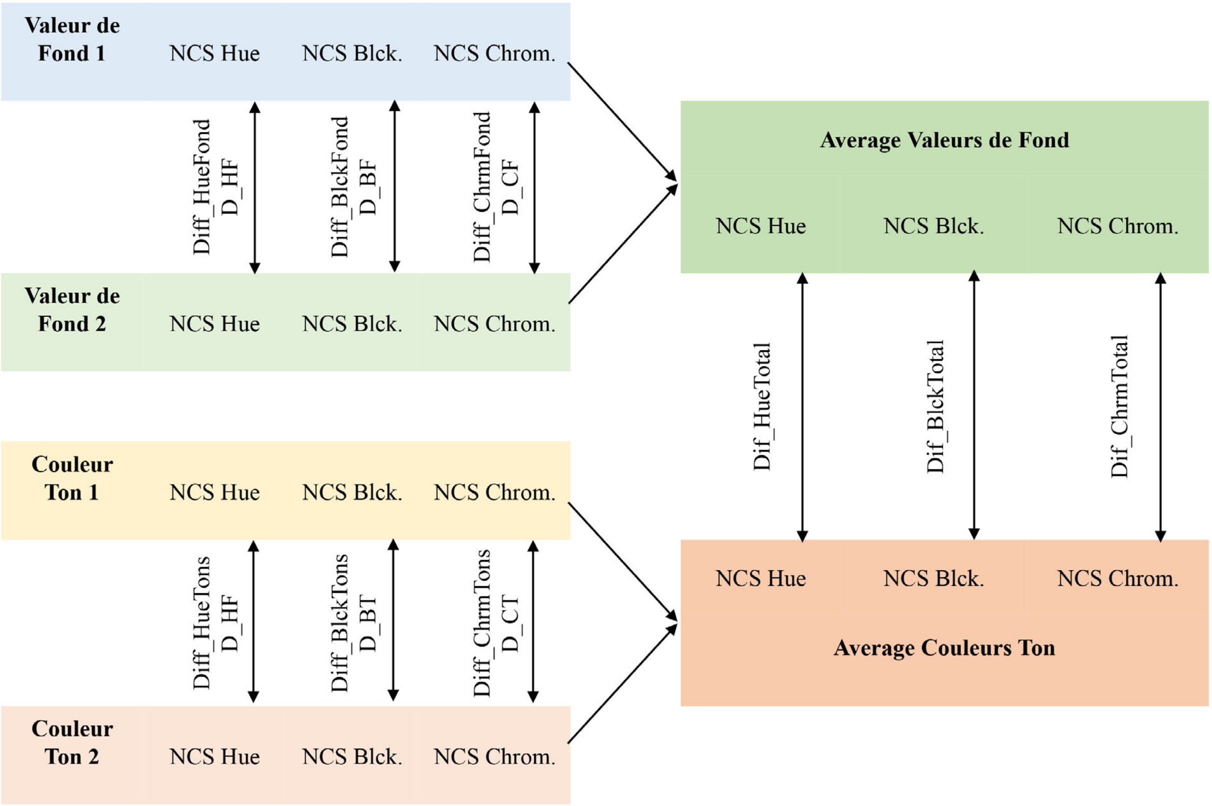

Valeur de Fond 1
NCS Hue
NCS Blck.
NCS Chrom.
Diff_HueFond D_HF
Diff_BlckFond D_BF
Diff_ChrmFond D_CF
Valeur de Fond 2
NCS Hue
NCS Blck.
NCS Chrom.
Average Valeurs de Fond
NCS Hue
NCS Blck.
NCS Chrom.
Dif_HueTotal
Dif_BlckTotal
Dif_ChrmTotal
Couleur Ton 1
NCS Hue
NCS Blck.
NCS Chrom.
Diff_HueTons D_HF
Diff_BlckTons D_BT
Diff_ChrmTons D_CT
Couleur Ton 2
NCS Hue
NCS Blck.
NCS Chrom.
NCS Hue
NCS Blck.
NCS Chrom.
Average Couleurs Ton

FIGURE 3 Scheme of the variables description and the analysis of the color combination criteria for a combination of four colors, two *Valeurs de Fond* and two *Couleurs Ton*

For the calculation of the hue average of two colors 1 and 2, if the absolute value ABS $(\text{hue1} - \text{hue2}) \leq 180$, the result is set as $(\text{hue1} + \text{hue2})/2$; if ABS $(\text{hue1} - \text{hue2}) > 180$, the result is set as $180 + (\text{hue1} + \text{hue2})/2$. For the calculation of the hue difference of two colors, if ABS $(\text{hue1} - \text{hue2}) \leq 180$, the result is set as ABS$(\text{hue1} - \text{hue2})$; if ABS $(\text{hue1} - \text{hue2}) > 180$, the result is set as 360-ABS$(\text{hue1} - \text{hue2})$. For the calculation of blackness average of two colors, the result is set as $(\text{Blck1} + \text{Black2})/2$, and for chromaticness average as $(\text{Chrm1} + \text{Chrm2})/2$. For the calculation of blackness difference of two colors, the result is set as ABS $(\text{Blck1} - \text{Black2})$, and for chromaticness difference as ABS $(\text{Chrm1} - \text{Chrm2})$.

3.4.2 | Variables for the analysis of the preference

The preference of current observers for each of the bedroom images was evaluated with a Likert scale and converted into values from 1 to 7. The preference of current observers for each individual color (43) was calculated as the mean value of the assessments for every bedroom containing that color as a *valeur de fond* or a *couleur ton*.

The preference of Le Corbusier for a single color is unknown, but it is logical to consider that Le Corbusier preferred those colors that appear more times all along the Salubra Keyboards. Certainly, the v*aleurs de fond* are the most numerous, as they belong at least to the 13 color combinations of the same keyboard. We calculated the frequency (%) of such a color in a combination in relation with the total amount of 4-colors combinations (312).

3.4.3 | Statistical analysis

We used an anonymized database with IBM SPSS software. The statistical tests were run for the descriptive analysis for the preference of the bedrooms with the following structure: (a) means comparison of individual color preference between current observers and Le Corbusier; (b) Analysis of variance (ANOVA) for the analysis of the influence in preference of the average/difference of Hue/Blackness/Chromaticness of *Valeurs de fond/Couleurs Ton*.

TABLE 1 Colors in order from the most to the least preferred according to current observers (left side) and Le Corbusier (right side)

	Current Observers	Le Corbusier	
Preference [1-7]	NCS Notation	NCS Notation	Frequency [%]
3.96	142 NCS S 2005-Y40R	060 NCS S 0515-Y30R	9.88
3.93	031 NCS S 2040-B10G	001 NCS S 0510-Y30R	8.11
3.85	010 NCS S 6502-B	122 NCS S 1020-Y60R	5.90
3.84	033 NCS S 1515-B50G	131 NCS S 3010-Y50R	4.42
3.79	140 NCS S 6502-Y	091 NCS S 1010-Y70R	3.83
3.79	034 NCS S 1010-B90G	112 NCS S 1015-Y70R	3.83
3.78	081 NCS S 1050-Y60R	013 NCS S 2002-G50Y	3.69
3.78	111 NCS S 2030-Y70R	120 NCS S 6020-Y80R	3.17
3.77	131 NCS S 3010-Y50R	121 NCS S 3030-Y70R	3.17
3.76	013 NCS S 2002-G50Y	011 NCS S 4000-N	3.02
3.75	130 NCS S 7005-Y80R	051 NCS S 2050-G30Y	2.95
3.74	023 NCS S 1015-B	110 NCS S 4040-Y70R	2.73
3.70	141 NCS S 4005-Y20R	030 NCS S 4040-R90B	2.51
3.69	024 NCS S 0804-B50G	032 NCS S 2020-B30G	2.51
3.67	032 NCS S 2020-B30G	022 NCS S 1515-R90B	2.21
3.67	060 NCS S 0515-Y30R	082 NCS S 0515-Y60R	2.21
3.66	041 NCS S 2020-B90G	020 NCS S 3050-R80B	1.99
3.65	011 NCS S 4000-N	090 NCS S 3060-Y90R	1.99
3.63	112 NCS S 1015-Y70R	012 NCS S 3500N	1.92
3.61	121 NCS S 3030-Y70R	024 NCS S 0804-B50G	1.84
3.60	122 NCS S 1020-Y60R	033 NCS S 1515-B50G	1.84
3.60	091 NCS S 1010-Y70R	053 NCS S 1030-G40Y	1.84
3.60	082 NCS S 0515-Y60R	130 NCS S 7005-Y80R	1.84
3.59	102 NCS S 1020-Y90R	050 NCS S 4040-G10Y	1.70
3.59	012 NCS S 3500N	142 NCS S 2005-Y40R	1.70
3.56	123 NCS S 1010-Y50R	010 NCS S 6502-B	1.62
3.54	120 NCS S 6020-Y80R	140 NCS S 6502-Y	1.62
3.53	021 NCS S 1030-R80B	034 NCS S 1010-B90G	1.40
3.53	052 NCS S 1040-G40Y	141 NCS S 4005-Y20R	1.40
3.51	022 NCS S 1515-R90B	021 NCS S 1030-R80B	1.33
3.50	080 NCS S 1060-Y60R	100 NCS S 4040-R	1.33
3.49	101 NCS S 3050-R10B	023 NCS S 1015-B	1.25
3.49	030 NCS S 4040-R90B	052 NCS S 1040-G40Y	1.25
3.48	040 NCS S 5020-G	040 NCS S 5020-G	1.03
3.48	100 NCS S 4040-R	041 NCS S 2020-B90G	1.03
3.46	110 NCS S 4040-Y70R	102 NCS S 1020-Y90R	1.03
3.38	090 NCS S 3060-Y90R	111 NCS S 2030-Y70R	1.03
3.28	020 NCS S 3050-R80B	042 NCS S 1510-G20Y	0.88
3.28	053 NCS S 1030-G40Y	101 NCS S 3050-R10B	0.88
3.14	051 NCS S 2050-G30Y	123 NCS S 1010-Y50R	0.88
3.14	001 NCS S 0510-Y30R	080 NCS S 1060-Y60R	0.59
3.05	050 NCS S 4040-G10Y	031 NCS S 2040-B10G	0.29
2.66	042 NCS S 1510-G20Y	081 NCS S 1050-Y60R	0.29

Note: The values refer to different scales: Current preference from 1 to 7, and frequency of a color among the 312 combinations in %.

4 | RESULTS

4.1 | Comparison of color preference between Le Corbusier and observers for individual colors: Means comparison

The preference for individual colors by Le Corbusier, measured as a frequency, receives a mean value between 0.29% and 9.88%, with an average of 2.37%. In an order from the most to the least preferred, they follow a kind-of linear tendency, with a clear preference for warm pastel colors (S 0515-Y30R; S 0510-Y30R; S 1020-Y60R, S 3010-Y50R, S 1010-Y70R, and S 1015-Y70R), followed by a random distribution of colors with different hues and nuances, and oranges as the least preferred colors (Table 1).

The preference of current observers for individual colors received a mean value between 2.66 (2-Dislike moderately) and 3.96 (4-Neither Like nor Dislike), with an average of 3.57 (3-Dislike slightly). In an order from the most to the least preferred, they follow a linear tendency with approximately cool pastel colors and light browns as the most preferred, followed by warm pastel colors, then vivid colors, and a clear drop in the last four colors that have a preference equal to or under 3.28 corresponding to greenish hues (S 1030-G40Y, S 2050-G30Y, S 0510-Y30R, S 4040-G10Y, S 1510-G20Y).

The comparison between Le Corbusier and current observers points out some differences. The warm pastel colors, which are the most preferred colors by Le Corbusier, are evaluated in an intermediate position by current observers. Generally speaking, the cool pastel colors are more preferred by current observers than by Le Corbusier. On the contrary, the most vivid colors, with more blackness and chromaticness, were more preferred by Le Corbusier than by current observers. The least preferred colors for Le Corbusier belong to orange while for current observers belong to green. Interestingly, the color S 0510-Y30R, which is the color closest to white in Salubra Keyboards, was the most preferred by Le Corbusier but received a low evaluation by current observers.

4.2 | Current preference for color combination criteria based on hue

4.2.1 | Influence of the hue of the *valeurs de fond* in preference: ANOVA Avr_HueFond and ANOVA Diff_HueFond

Results of the Pearson correlation indicated that there was a significant negative association between preference and average Hue for *valeurs de fond*, ($r(310) = -.135$, $P = .017$). The tendency is that when the hues of *valeurs de fond* are between 180° and 240° (NCS G to B30G), combinations are more preferred, and there is a clear drop in preference when hues are between 300° and 360° (NCS R60B to R) (Figure 4A).

Results of the Pearson correlation indicated that there was a significant negative association between preference and difference in Hue for *valeurs de fond*, ($r(310) = -.203$, $P < .001$). Those color combinations with a hue difference in *valeurs de fond* between 0° and 90° (<10 NCS Hue families) are most preferred. Those *valeurs de fond* with a difference in hue bigger than 90° suffer a significant drop in preference (Figure 4B).

4.2.2 | Influence of the hue of the *couleurs tons* in preference: ANOVA Avr_HueTons and ANOVA Diff_HueTons

There is no significant correlation between Average NCS Hue family of *couleurs tons* and preference, neither there is any significant correlation between differences in NCS Hue family of *couleurs tons* and preference.

4.2.3 | Influence of the hue difference between average *couleurs tons* and average *valeurs de fond* in preference ANOVA Dif_Hue_Total

Results of the Pearson correlation indicated that there was a significant negative correlation between preference, and the difference between the average hues for the two *valeurs de fond* and the average hue for the two *couleurs tons*, ($r(310) = -.136$, $P = .017$). When difference in hue between them is bigger than 30° (>3 NCS Hue families), there is a significant drop in preference (Figure 5; Table 2).

4.3 | Current preference for color combination criteria based on blackness

4.3.1 | Influence of the blackness of the *valeurs de fond* in preference: ANOVA Avr_BlckFonds and ANOVA Diff_ BlckFond

Results of the Pearson correlation indicated that there was a significant negative correlation between preference, and average between the Blackness for the two *valeurs de fond*, ($\text{r}(310) = -.155$, $P = .006$). When the average between the Blackness for *valeurs de fond* is higher than 10%, there is a significant drop in Preference (Figure 6A). The most preferred color combinations, and so containing *valeurs de fond* with Average Blackness ≤10%, belong to the Keyboards *Mur I* and *II*.

Results of the Pearson correlation indicated that there was a significant negative association between preference, and difference between the Blackness for the two *Valeurs de fond*, ($\text{r}(310) = -.238$, $P < .001$). When difference between the Blackness for *Valeurs de fond* increases, preference decreases (Figure 6B). When difference in blackness is bigger than 20%, there is a significant drop in preference.

4.3.2 | Influence of the blackness of the *couleurs tons* in preference: ANOVA Avr_BlckTons and ANOVA Diff_ BlckTon

There was no significant correlation between Average NCS Blackness of *couleurs tons* and preference, neither there was any significant correlation between

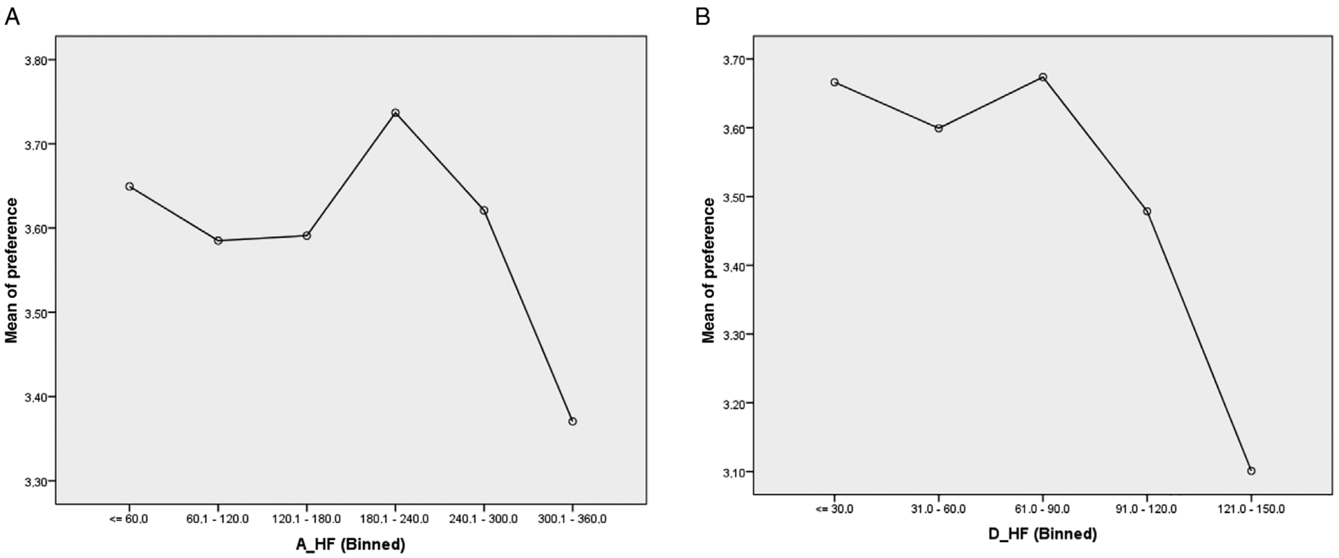


FIGURE 4 A, Bedroom preference according to the average hue of *valeurs de fond* (A_HF). B, Bedroom preference according to the difference in hue of *valeurs de fond* (D_HF)

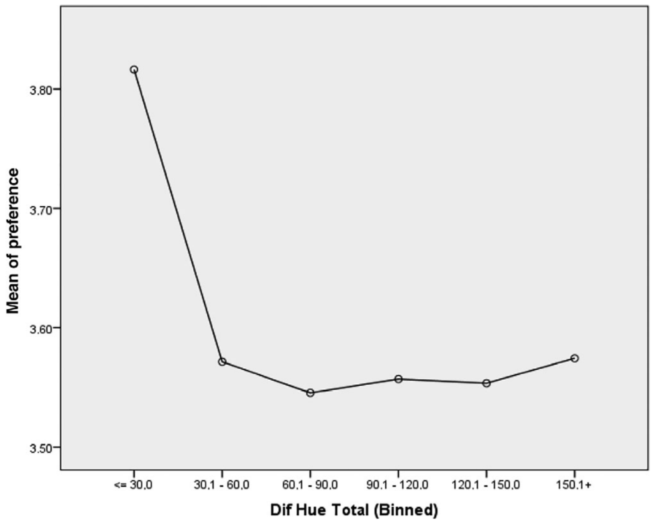


FIGURE 5 Bedroom preference according to the difference in hue between average of *valeurs de fond* and average *couleurs tons* (Dif Hue Total)

difference in NCS Blackness of *couleurs tons* and preference.

4.3.3 | Influence of the blackness difference between average *couleurs tons* and average *valeurs de fond* in preference: ANOVA Dif_Blck_Total

Results of the Pearson correlation indicated that there was a significant positive correlation between preference, and the difference between the average blackness of the two *valeurs de fonds* and the two *couleurs tons*, (r (310) = .219, $P < .001$). When difference in Blackness between them increases, preference increases (Figure 7; Table 3).

4.4 | Current preference for color combination criteria based on chromaticness

4.4.1 | Influence of the chromaticness of the *valeurs de fond* in preference: ANOVA Avr_Chrm_Fonds and ANOVA Diff_ChrmFond

Results of the Pearson correlation indicated that there was a significant negative correlation between preference and chromaticness average of the two *valeurs de fond*, ($r(310) = -.167$, $P = .016$). The least preference is when chromaticness average of *valeurs de fond* is between 20 and 30%. Therefore, it is important that *valeurs de fond* have a low chromaticness (≤20%) (Figure 8A).

Results of the Pearson correlation indicated that there was a significant negative correlation between preference, and chromaticness difference between the two *valeurs de fond*, ($r(310) = -.268$, $P < .001$). Preference decreases when chromaticness difference between *valeurs de fond* increases (Figure 8B).

TABLE 2 Color combinations with a hue difference <30° between the average hue of the two *valeurs de fond* and the average hue of the two *couleurs tons*, and so most preferred color combinations

Clavier	*Valeur de Fond 1*	*Coluleur ton 1*	*Coluleur ton 2*	*Valeur de Fond 2*
Velour I	001 NCS S 0510-Y30R	111 NCS S 2030-Y70R	110 NCS S 4040-Y70R	012 NCS S 3500N
Velour I	001 NCS S 0510-Y30R	112 NCS S 1015-Y70R	111 NCS S 2030-Y70R	012 NCS S 3500N
Mur I	122 NCS S 1020-Y60R	131 NCS S 3010-Y50R	130 NCS S 7005-Y80R	091 NCS S 1010-Y70R
Mur I	112 NCS S 1015-Y70R	131 NCS S 3010-Y50R	130 NCS S 7005-Y80R	122 NCS S 1020-Y60R
Sable II	131 NCS S 3010-Y50R	142 NCS S 2005-Y40R	001 NCS S 0510-Y30R	060 NCS S 0515-Y30R
Bigarré I	030 NCS S 4040-R90B	010 NCS S 6502-B	091 NCS S 1010-Y70R	130 NCS S 7005-Y80R
Bigarré II	120 NCS S 6020-Y80R	120 NCS S 6020-Y80R	121 NCS S 3030-Y70R	121 NCS S 3030-Y70R
Bigarré II	110 NCS S 4040-Y70R	120 NCS S 6020-Y80R	121 NCS S 3030-Y70R	120 NCS S 6020-Y80R
Velour I	001 NCS S 0510-Y30R	110 NCS S 4040-Y70R	130 NCS S 7005-Y80R	012 NCS S 3500N
Velour I	001 NCS S 0510-Y30R	120 NCS S 6020-Y80R	121 NCS S 3030-Y70R	012 NCS S 3500N
Velour I	001 NCS S 0510-Y30R	122 NCS S 1020-Y60R	112 NCS S 1015-Y70R	012 NCS S 3500N
Velour I	001 NCS S 0510-Y30R	121 NCS S 3030-Y70R	122 NCS S 1020-Y60R	012 NCS S 3500N
Mur I	122 NCS S 1020-Y60R	130 NCS S 7005-Y80R	142 NCS S 2005-Y40R	091 NCS S 1010-Y70R
Mur I	112 NCS S 1015-Y70R	130 NCS S 7005-Y80R	142 NCS S 2005-Y40R	122 NCS S 1020-Y60R
Bigarré I	011 NCS S 4000-N	011 NCS S 4000-N	010 NCS S 6502-B	030 NCS S 4040-R90B
Bigarré II	120 NCS S 6020-Y80R	091 NCS S 1010-Y70R	090 NCS S 3060-Y90R	121 NCS S 3030-Y70R
Bigarré II	120 NCS S 6020-Y80R	110 NCS S 4040-Y70R	112 NCS S 1015-Y70R	121 NCS S 3030-Y70R
Bigarré III	001 NCS S 0510-Y30R	041 NCS S 2020-B90G	091 NCS S 1010-Y70R	050 NCS S 4040-G10Y
Bigarré II	110 NCS S 4040-Y70R	091 NCS S 1010-Y70R	090 NCS S 3060-Y90R	120 NCS S 6020-Y80R
Bigarré II	110 NCS S 4040-Y70R	110 NCS S 4040-Y70R	112 NCS S 1015-Y70R	120 NCS S 6020-Y80R
Velour II	001 NCS S 0510-Y30R	082 NCS S 0515-Y60R	081 NCS S 1050-Y60R	012 NCS S 3500N
Velour II	001 NCS S 0510-Y30R	081 NCS S 1050-Y60R	080 NCS S 1060-Y60R	012 NCS S 3500N
Velour II	001 NCS S 0510-Y30R	091 NCS S 1010-Y70R	090 NCS S 3060-Y90R	012 NCS S 3500N
Sable I	082 NCS S 0515-Y60R	130 NCS S 7005-Y80R	131 NCS S 3010-Y50R	131 NCS S 3010-Y50R
Sable II	082 NCS S 0515-Y60R	080 NCS S 1060-Y60R	111 NCS S 2030-Y70R	131 NCS S 3010-Y50R
Bigarré I	011 NCS S 4000-N	010 NCS S 6502-B	091 NCS S 1010-Y70R	030 NCS S 4040-R90B
Bigarré II	120 NCS S 6020-Y80R	121 NCS S 3030-Y70R	122 NCS S 1020-Y60R	121 NCS S 3030-Y70R
Bigarré II	120 NCS S 6020-Y80R	122 NCS S 1020-Y60R	110 NCS S 4040-Y70R	121 NCS S 3030-Y70R
Bigarré II	120 NCS S 6020-Y80R	090 NCS S 3060-Y90R	120 NCS S 6020-Y80R	121 NCS S 3030-Y70R
Bigarré III	001 NCS S 0510-Y30R	001 NCS S 0510-Y30R	034 NCS S 1010-B90G	050 NCS S 4040-G10Y
Bigarré II	110 NCS S 4040-Y70R	121 NCS S 3030-Y70R	122 NCS S 1020-Y60R	120 NCS S 6020-Y80R
Bigarré II	110 NCS S 4040-Y70R	122 NCS S 1020-Y60R	110 NCS S 4040-Y70R	120 NCS S 6020-Y80R
Bigarré III	020 NCS S 3050-R80B	100 NCS S 4040-R	011 NCS S 4000-N	001 NCS S 0510-Y30R
Velour II	013 NCS S 2002-G50Y	040 NCS S 5020-G	082 NCS S 0515-Y60R	001 NCS S 0510-Y30R
Sable II	082 NCS S 0515-Y60R	142 NCS S 2005-Y40R	001 NCS S 0510-Y30R	131 NCS S 3010-Y50R
Sable I	131 NCS S 3010-Y50R	011 NCS S 4000-N	013 NCS S 2002-G50Y	060 NCS S 0515-Y30R
Bigarré I	030 NCS S 4040-R90B	011 NCS S 4000-N	010 NCS S 6502-B	130 NCS S 7005-Y80R
Bigarré III	001 NCS S 0510-Y30R	034 NCS S 1010-B90G	102 NCS S 1020-Y90R	050 NCS S 4040-G10Y
Velour I	001 NCS S 0510-Y30R	140 NCS S 6502-Y	100 NCS S 4040-R	012 NCS S 3500N
Mur I	122 NCS S 1020-Y60R	100 NCS S 4040-R	121 NCS S 3030-Y70R	091 NCS S 1010-Y70R
Mur I	122 NCS S 1020-Y60R	001 NCS S 0510-Y30R	131 NCS S 3010-Y50R	091 NCS S 1010-Y70R
Mur I	112 NCS S 1015-Y70R	100 NCS S 4040-R	121 NCS S 3030-Y70R	122 NCS S 1020-Y60R
Mur I	112 NCS S 1015-Y70R	001 NCS S 0510-Y30R	131 NCS S 3010-Y50R	122 NCS S 1020-Y60R
Sable II	131 NCS S 3010-Y50R	140 NCS S 6502-Y	142 NCS S 2005-Y40R	060 NCS S 0515-Y30R
Sable II	082 NCS S 0515-Y60R	111 NCS S 2030-Y70R	102 NCS S 1020-Y90R	131 NCS S 3010-Y50R
Sable I	131 NCS S 3010-Y50R	130 NCS S 7005-Y80R	131 NCS S 3010-Y50R	060 NCS S 0515-Y30R
Sable II	131 NCS S 3010-Y50R	080 NCS S 1060-Y60R	111 NCS S 2030-Y70R	060 NCS S 0515-Y30R
Velour I	001 NCS S 0510-Y30R	101 NCS S 3050-R10B	102 NCS S 1020-Y90R	012 NCS S 3500N
Sable II	082 NCS S 0515-Y60R	101 NCS S 3050-R10B	080 NCS S 1060-Y60R	131 NCS S 3010-Y50R
Velour I	001 NCS S 0510-Y30R	130 NCS S 7005-Y80R	140 NCS S 6502-Y	012 NCS S 3500N
Sable I	082 NCS S 0515-Y60R	011 NCS S 4000-N	013 NCS S 2002-G50Y	131 NCS S 3010-Y50R
Velour I	001 NCS S 0510-Y30R	100 NCS S 4040-R	101 NCS S 3050-R10B	012 NCS S 3500N

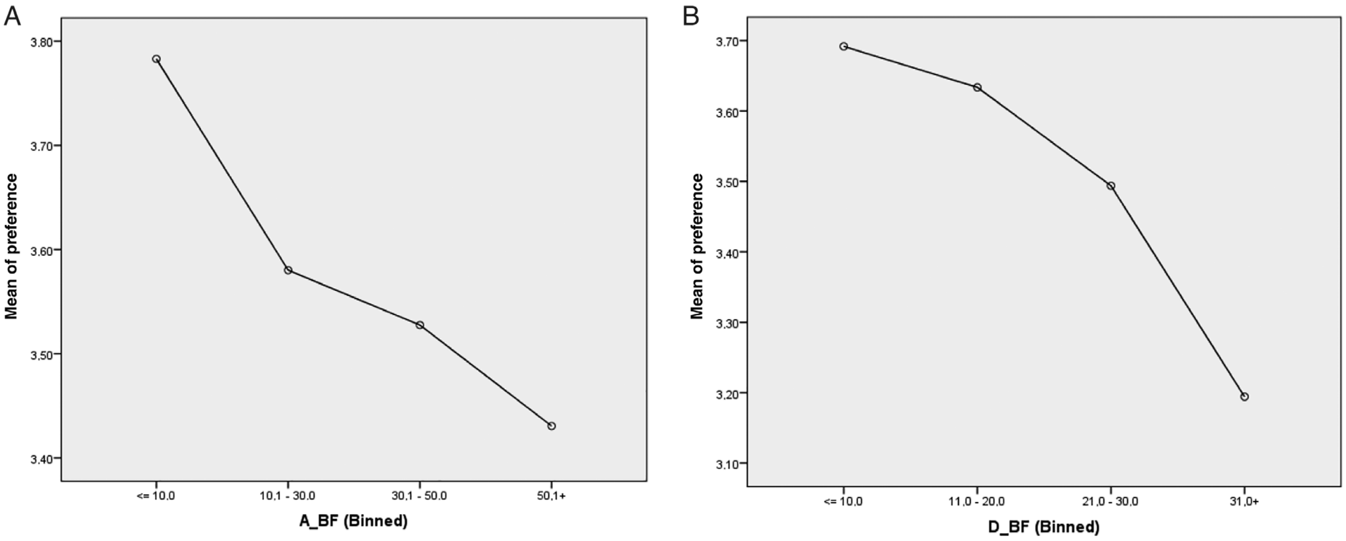


FIGURE 6 A, Bedroom preference according to the average blackness of *valeurs de fond* (A_BF). B, Bedroom preference according to the difference in blackness of *valeurs de fond* (D_BF)

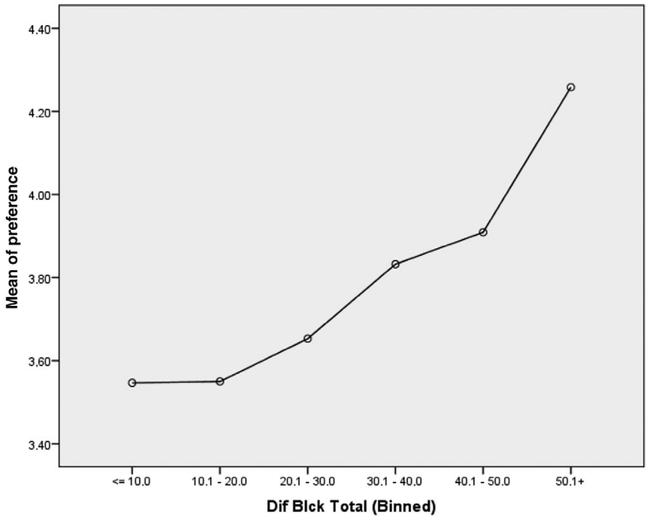


FIGURE 7 Bedroom preference according to the blackness difference between average of the two *valeurs de fond* and average of the two *couleurs tons* (Dif Blck Total)

4.4.2 | Influence of the chromaticness of the *couleurs tons* in preference: ANOVA Avr_Chrm_Tons and ANOVA Diff_ ChrmTon

Results of the Pearson correlation indicated that there was a significant negative association between preference, and chromaticness average of the two *couleurs tons*, (r(310) = −.384, $P < .001$). Preference decreases when chromaticness Average between *couleurs tons* increases (Figure 9A).

Results of the Pearson correlation indicated that there was a significant negative correlation between preference and chromaticness difference between the two *couleurs tons*, (r(310) = −.344, P = .032). Preference decreases when chromaticness difference between *couleurs tons* increases (Figure 9B).

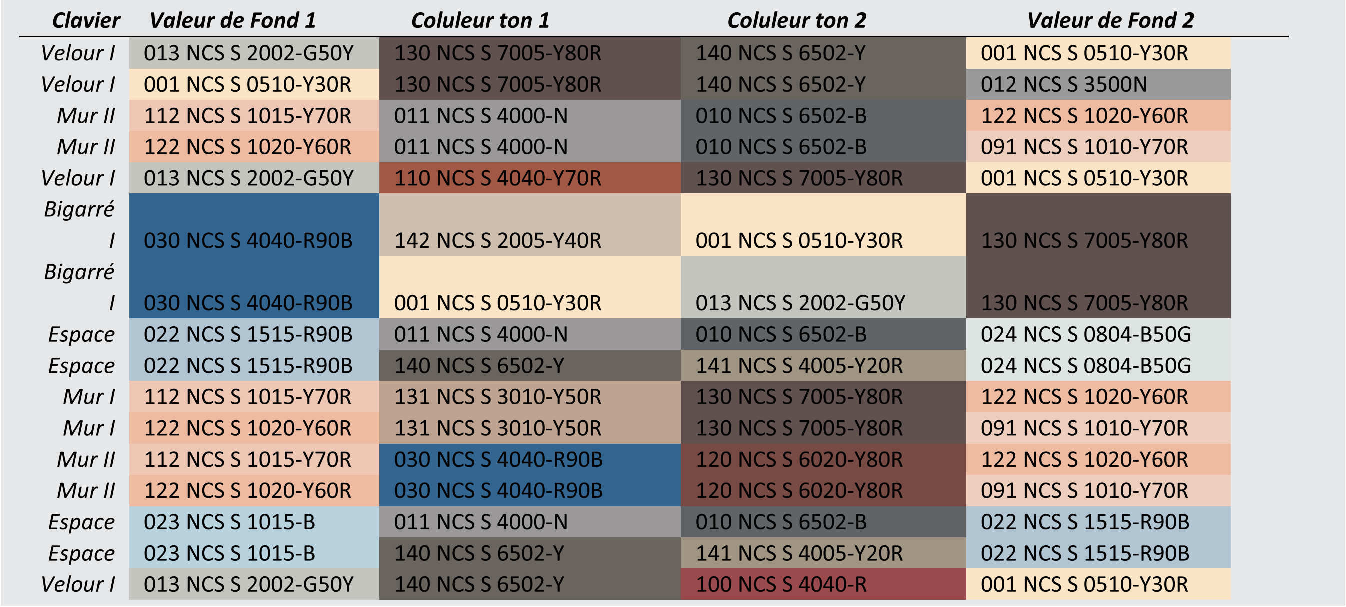
4.4.3 | Influence of the chromaticness difference between average *couleurs tons* and average *valeurs de fond* in preference (ANOVA Dif_Chrm_Total)

Results of the Pearson correlation indicated that there was a significant negative correlation between preference, and the difference between the average chromaticness of the two *valeurs de fonds* and the two *couleurs tons*, (r(310) = −.121, $P < .001$). Preference decreases when chromaticness difference between *valeurs de fond* and *couleurs tons* increases over 20% (Figure 10; Table 4).

5 | DISCUSSION OF THE RESULTS

We performed a study to investigate the color combination criteria that orient the preference of current observers for an interior design, after Le Corbusier's 1931 *Salubra Claviers*, exploring the three perceptual variables that describe a color in NCS (hue, blackness, and chromaticness) in 312 color combinations with 4 colors in different extensions: 2 *couleurs tons*, and 2 *valeurs de fond*. To that aim, the interior of a bedroom from the Swiss Pavilion (Le Corbusier, 1930-1931) was chosen as a case study (Table 5). Participants were 644 students of architecture and interior design in Western Europe and

TABLE 3 Color combinations with a total NCS blackness difference ≥40% between average of the two *valeurs de fond* and average of the two *couleurs tons*, and so most preferred



Clavier	*Valeur de Fond 1*	*Coluleur ton 1*	*Coluleur ton 2*	*Valeur de Fond 2*
Velour I	013 NCS S 2002-G50Y	130 NCS S 7005-Y80R	140 NCS S 6502-Y	001 NCS S 0510-Y30R
Velour I	001 NCS S 0510-Y30R	130 NCS S 7005-Y80R	140 NCS S 6502-Y	012 NCS S 3500N
Mur II	112 NCS S 1015-Y70R	011 NCS S 4000-N	010 NCS S 6502-B	122 NCS S 1020-Y60R
Mur II	122 NCS S 1020-Y60R	011 NCS S 4000-N	010 NCS S 6502-B	091 NCS S 1010-Y70R
Velour I	013 NCS S 2002-G50Y	110 NCS S 4040-Y70R	130 NCS S 7005-Y80R	001 NCS S 0510-Y30R
Bigarré I	030 NCS S 4040-R90B	142 NCS S 2005-Y40R	001 NCS S 0510-Y30R	130 NCS S 7005-Y80R
Bigarré I	030 NCS S 4040-R90B	001 NCS S 0510-Y30R	013 NCS S 2002-G50Y	130 NCS S 7005-Y80R
Espace	022 NCS S 1515-R90B	011 NCS S 4000-N	010 NCS S 6502-B	024 NCS S 0804-B50G
Espace	022 NCS S 1515-R90B	140 NCS S 6502-Y	141 NCS S 4005-Y20R	024 NCS S 0804-B50G
Mur I	112 NCS S 1015-Y70R	131 NCS S 3010-Y50R	130 NCS S 7005-Y80R	122 NCS S 1020-Y60R
Mur I	122 NCS S 1020-Y60R	131 NCS S 3010-Y50R	130 NCS S 7005-Y80R	091 NCS S 1010-Y70R
Mur II	112 NCS S 1015-Y70R	030 NCS S 4040-R90B	120 NCS S 6020-Y80R	122 NCS S 1020-Y60R
Mur II	122 NCS S 1020-Y60R	030 NCS S 4040-R90B	120 NCS S 6020-Y80R	091 NCS S 1010-Y70R
Espace	023 NCS S 1015-B	011 NCS S 4000-N	010 NCS S 6502-B	022 NCS S 1515-R90B
Espace	023 NCS S 1015-B	140 NCS S 6502-Y	141 NCS S 4005-Y20R	022 NCS S 1515-R90B
Velour I	013 NCS S 2002-G50Y	140 NCS S 6502-Y	100 NCS S 4040-R	001 NCS S 0510-Y30R

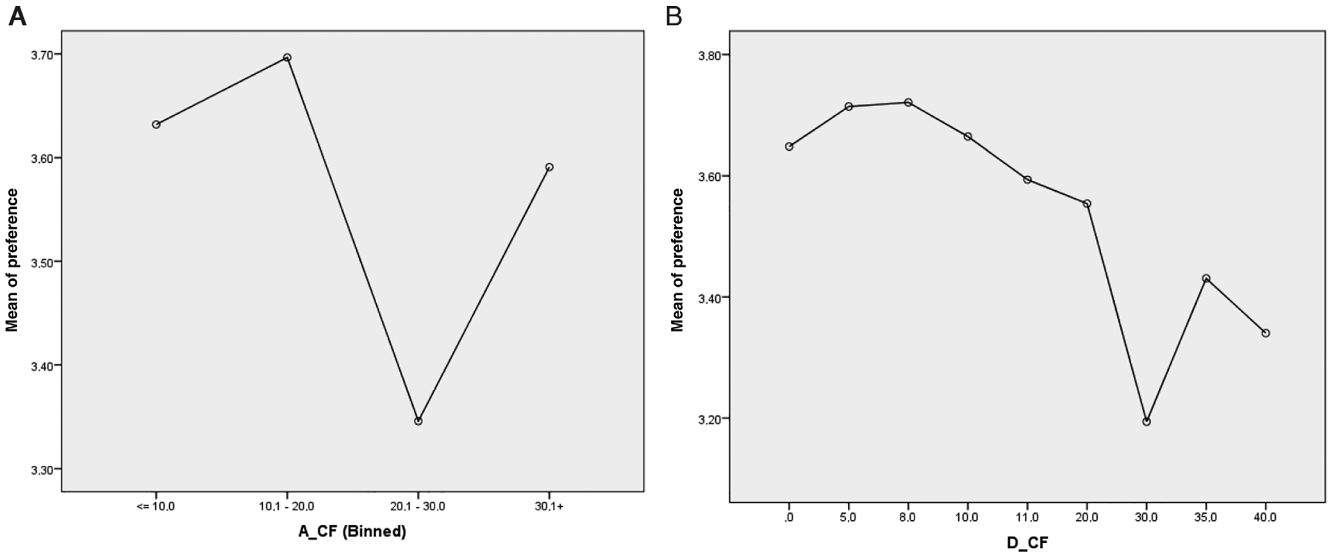


FIGURE 8 A, Bedroom preference according to the average chromaticness of the two *valeurs de fond* (A_CF). B, Bedroom preference according to the chromaticness difference of the two *valeurs de fond* (D_CF)

Near East, who evaluated with a Likert scale their preference for virtual images via an online survey. From a methodological point of view, the evaluation of the colors of an interior via a 2D digital image is a limitation of the study that needs to be pointed out, despite previous experiments have largely used flat images, and internet surveys have been validated as appropriate techniques for the visual assessment of environments.[35] In our own experience, when involving 360 VR interior spaces are compared with traditional photographs, there are just slight differences in the results of color preference.[3] Nevertheless, future research should consider the possible bias of observing colors mediated by a screen and not on site.

We performed a first analysis to compare the preference for the individual colors by Le Corbusier, measured as a frequency of the number of times that a singular color appeared in the 312 color combinations; with the preference expressed by current observers in a Likert scale from 1 to 7. Le Corbusier tended to prefer warm pastel colors (S 0515-Y30R, S 0510-Y30R, S 1020-Y60R, S 3010-Y50R, S 1010-Y70R, and S 1015-Y70R) while current

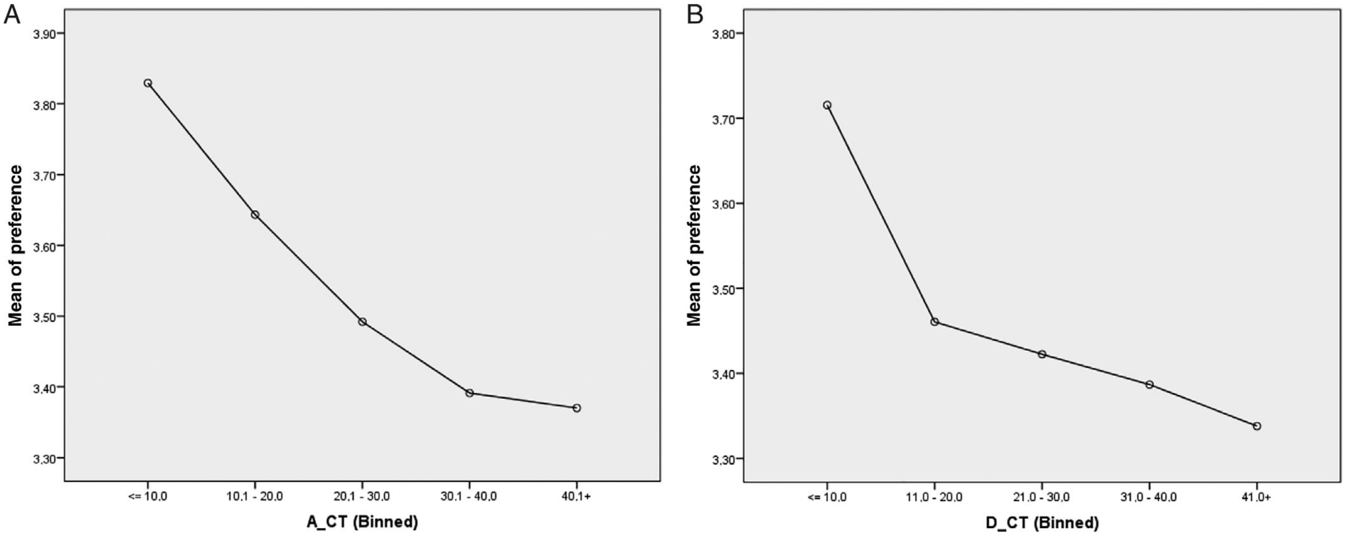


FIGURE 9 A, Bedroom preference according to the average chromaticness of *couleurs tons* (A_CT). B, Bedroom preference according to the difference in chromaticness of *couleurs tons* (D-CT)

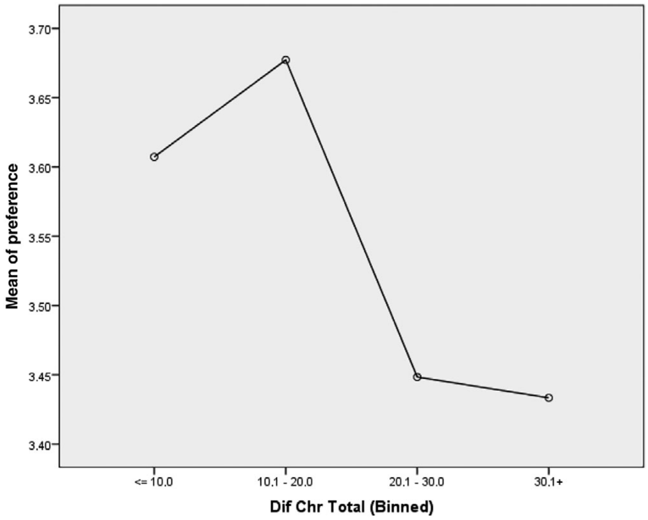
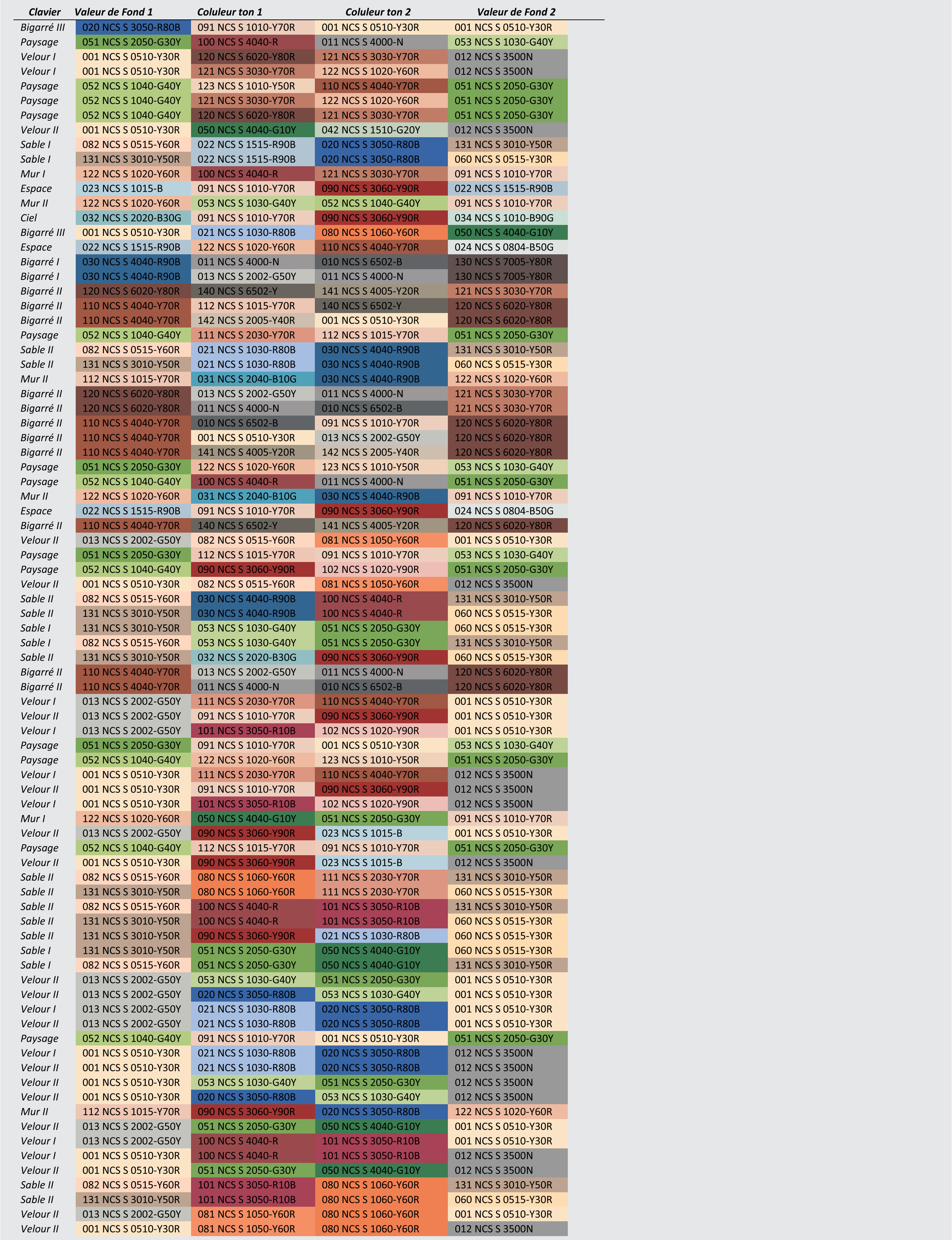


FIGURE 10 Bedroom preference according to the chromaticness difference between average of *valeurs de fond* and average *couleurs tons* (Dif Chr Total)

observers tended to prefer cool pastel colors (S 2005-Y40R, S 2040-B10G, S 6502-B, S 1515-B50G, S 6502-Y, and S 1010-B90G). In general terms, the most vivid colors in Salubra, those with more blackness and chromaticness, were more preferred by Le Corbusier than by current observers. The least preferred colors for Le Corbusier belonged to oranges, while for current observers belonged to green. In line with Le Corbusier's least preferred color, recent studies demonstrated orange to be considered "vulgar" and undesired for bedrooms.[6] Regarding the low ratings for green among our young respondents, results are coherent with studies demonstrating that green is more preferred by people over 50 years old compared with youngers.[21] Lastly, we found that the color S 0510-Y30R, which is the closest to white in Salubra keyboards, was a frequent color in Le Corbusier's combinations but received a low evaluation by current observers. Conversely, many studies have reported white to be the most preferred color for bedrooms.[5] It seems that in the case of the Swiss Pavilion bedrooms, the extension of the white ceiling indicated by Le Corbusier is wide enough and participants preferred lateral walls with hues different to white.[34]

The results about current preference for bedrooms with colors combination criteria based on hue indicate that the hue of *valuers de fond* is more significant in preference than the hue of *couleurs tons*, as we have not found any significant correlation with *couleurs tons*. When the hue average of *valeurs de fond* are between 180° and 240° (NCS G to B30G), combinations are more preferred, and there is a clear drop in preference when hues are between 300° and 360° (NCS R60B to R). In general, when the hues of the *valeurs de fond* are close in the color wheel (≤10 NCS Hue families), the bedrooms are more preferred. Similarly, bedrooms are more preferred when difference in hue is ≤3 NCS Hue families, between the average hues for the two *valeurs de fond* and the average hue for the two *couleurs tons*. In brief, the two *couleurs tons* may have hues with certain distance between them, but the two *valeurs de fond* should have hues that are close between them, and close to the hues of the two *couleurs tons*. These findings are aligned with those by Ou et Luo, who found that the less the hue difference between the constituent colors in a color pair, the more likely it is that the color pair appears harmonious.[17] Our results are also coherent with the findings by

TABLE 4 Color combinations with chromaticness difference ≥20% between average of the two *valeurs de fond* and average of the two *couleurs tons*, and so least preferred



Clavier	*Valeur de Fond 1*	*Coluleur ton 1*	*Coluleur ton 2*	*Valeur de Fond 2*
Bigarré III	020 NCS S 3050-R80B	091 NCS S 1010-Y70R	001 NCS S 0510-Y30R	001 NCS S 0510-Y30R
Paysage	051 NCS S 2050-G30Y	100 NCS S 4040-R	011 NCS S 4000-N	053 NCS S 1030-G40Y
Velour I	001 NCS S 0510-Y30R	120 NCS S 6020-Y80R	121 NCS S 3030-Y70R	012 NCS S 3500N
Velour I	001 NCS S 0510-Y30R	121 NCS S 3030-Y70R	122 NCS S 1020-Y60R	012 NCS S 3500N
Paysage	052 NCS S 1040-G40Y	123 NCS S 1010-Y50R	110 NCS S 4040-Y70R	051 NCS S 2050-G30Y
Paysage	052 NCS S 1040-G40Y	121 NCS S 3030-Y70R	122 NCS S 1020-Y60R	051 NCS S 2050-G30Y
Paysage	052 NCS S 1040-G40Y	120 NCS S 6020-Y80R	121 NCS S 3030-Y70R	051 NCS S 2050-G30Y
Velour II	001 NCS S 0510-Y30R	050 NCS S 4040-G10Y	042 NCS S 1510-G20Y	012 NCS S 3500N
Sable I	082 NCS S 0515-Y60R	022 NCS S 1515-R90B	020 NCS S 3050-R80B	131 NCS S 3010-Y50R
Sable I	131 NCS S 3010-Y50R	022 NCS S 1515-R90B	020 NCS S 3050-R80B	060 NCS S 0515-Y30R
Mur I	122 NCS S 1020-Y60R	100 NCS S 4040-R	121 NCS S 3030-Y70R	091 NCS S 1010-Y70R
Espace	023 NCS S 1015-B	091 NCS S 1010-Y70R	090 NCS S 3060-Y90R	022 NCS S 1515-R90B
Mur II	122 NCS S 1020-Y60R	053 NCS S 1030-G40Y	052 NCS S 1040-G40Y	091 NCS S 1010-Y70R
Ciel	032 NCS S 2020-B30G	091 NCS S 1010-Y70R	090 NCS S 3060-Y90R	034 NCS S 1010-B90G
Bigarré III	001 NCS S 0510-Y30R	021 NCS S 1030-R80B	080 NCS S 1060-Y60R	050 NCS S 4040-G10Y
Espace	022 NCS S 1515-R90B	122 NCS S 1020-Y60R	110 NCS S 4040-Y70R	024 NCS S 0804-B50G
Bigarré I	030 NCS S 4040-R90B	011 NCS S 4000-N	010 NCS S 6502-B	130 NCS S 7005-Y80R
Bigarré I	030 NCS S 4040-R90B	013 NCS S 2002-G50Y	011 NCS S 4000-N	130 NCS S 7005-Y80R
Bigarré II	120 NCS S 6020-Y80R	140 NCS S 6502-Y	141 NCS S 4005-Y20R	121 NCS S 3030-Y70R
Bigarré II	110 NCS S 4040-Y70R	112 NCS S 1015-Y70R	140 NCS S 6502-Y	120 NCS S 6020-Y80R
Bigarré II	110 NCS S 4040-Y70R	142 NCS S 2005-Y40R	001 NCS S 0510-Y30R	120 NCS S 6020-Y80R
Paysage	052 NCS S 1040-G40Y	111 NCS S 2030-Y70R	112 NCS S 1015-Y70R	051 NCS S 2050-G30Y
Sable II	082 NCS S 0515-Y60R	021 NCS S 1030-R80B	030 NCS S 4040-R90B	131 NCS S 3010-Y50R
Sable II	131 NCS S 3010-Y50R	021 NCS S 1030-R80B	030 NCS S 4040-R90B	060 NCS S 0515-Y30R
Mur II	112 NCS S 1015-Y70R	031 NCS S 2040-B10G	030 NCS S 4040-R90B	122 NCS S 1020-Y60R
Bigarré II	120 NCS S 6020-Y80R	013 NCS S 2002-G50Y	011 NCS S 4000-N	121 NCS S 3030-Y70R
Bigarré II	120 NCS S 6020-Y80R	011 NCS S 4000-N	010 NCS S 6502-B	121 NCS S 3030-Y70R
Bigarré II	110 NCS S 4040-Y70R	010 NCS S 6502-B	091 NCS S 1010-Y70R	120 NCS S 6020-Y80R
Bigarré II	110 NCS S 4040-Y70R	001 NCS S 0510-Y30R	013 NCS S 2002-G50Y	120 NCS S 6020-Y80R
Bigarré II	110 NCS S 4040-Y70R	141 NCS S 4005-Y20R	142 NCS S 2005-Y40R	120 NCS S 6020-Y80R
Paysage	051 NCS S 2050-G30Y	122 NCS S 1020-Y60R	123 NCS S 1010-Y50R	053 NCS S 1030-G40Y
Paysage	052 NCS S 1040-G40Y	100 NCS S 4040-R	011 NCS S 4000-N	051 NCS S 2050-G30Y
Mur II	122 NCS S 1020-Y60R	031 NCS S 2040-B10G	030 NCS S 4040-R90B	091 NCS S 1010-Y70R
Espace	022 NCS S 1515-R90B	091 NCS S 1010-Y70R	090 NCS S 3060-Y90R	024 NCS S 0804-B50G
Bigarré II	110 NCS S 4040-Y70R	140 NCS S 6502-Y	141 NCS S 4005-Y20R	120 NCS S 6020-Y80R
Velour II	013 NCS S 2002-G50Y	082 NCS S 0515-Y60R	081 NCS S 1050-Y60R	001 NCS S 0510-Y30R
Paysage	051 NCS S 2050-G30Y	112 NCS S 1015-Y70R	091 NCS S 1010-Y70R	053 NCS S 1030-G40Y
Paysage	052 NCS S 1040-G40Y	090 NCS S 3060-Y90R	102 NCS S 1020-Y90R	051 NCS S 2050-G30Y
Velour II	001 NCS S 0510-Y30R	082 NCS S 0515-Y60R	081 NCS S 1050-Y60R	012 NCS S 3500N
Sable II	082 NCS S 0515-Y60R	030 NCS S 4040-R90B	100 NCS S 4040-R	131 NCS S 3010-Y50R
Sable II	131 NCS S 3010-Y50R	030 NCS S 4040-R90B	100 NCS S 4040-R	060 NCS S 0515-Y30R
Sable I	131 NCS S 3010-Y50R	053 NCS S 1030-G40Y	051 NCS S 2050-G30Y	060 NCS S 0515-Y30R
Sable I	082 NCS S 0515-Y60R	053 NCS S 1030-G40Y	051 NCS S 2050-G30Y	131 NCS S 3010-Y50R
Sable II	131 NCS S 3010-Y50R	032 NCS S 2020-B30G	090 NCS S 3060-Y90R	060 NCS S 0515-Y30R
Bigarré II	110 NCS S 4040-Y70R	013 NCS S 2002-G50Y	011 NCS S 4000-N	120 NCS S 6020-Y80R
Bigarré II	110 NCS S 4040-Y70R	011 NCS S 4000-N	010 NCS S 6502-B	120 NCS S 6020-Y80R
Velour I	013 NCS S 2002-G50Y	111 NCS S 2030-Y70R	110 NCS S 4040-Y70R	001 NCS S 0510-Y30R
Velour II	013 NCS S 2002-G50Y	091 NCS S 1010-Y70R	090 NCS S 3060-Y90R	001 NCS S 0510-Y30R
Velour I	013 NCS S 2002-G50Y	101 NCS S 3050-R10B	102 NCS S 1020-Y90R	001 NCS S 0510-Y30R
Paysage	051 NCS S 2050-G30Y	091 NCS S 1010-Y70R	001 NCS S 0510-Y30R	053 NCS S 1030-G40Y
Paysage	052 NCS S 1040-G40Y	122 NCS S 1020-Y60R	123 NCS S 1010-Y50R	051 NCS S 2050-G30Y
Velour I	001 NCS S 0510-Y30R	111 NCS S 2030-Y70R	110 NCS S 4040-Y70R	012 NCS S 3500N
Velour II	001 NCS S 0510-Y30R	091 NCS S 1010-Y70R	090 NCS S 3060-Y90R	012 NCS S 3500N
Velour I	001 NCS S 0510-Y30R	101 NCS S 3050-R10B	102 NCS S 1020-Y90R	012 NCS S 3500N
Mur I	122 NCS S 1020-Y60R	050 NCS S 4040-G10Y	051 NCS S 2050-G30Y	091 NCS S 1010-Y70R
Velour II	013 NCS S 2002-G50Y	090 NCS S 3060-Y90R	023 NCS S 1015-B	001 NCS S 0510-Y30R
Paysage	052 NCS S 1040-G40Y	112 NCS S 1015-Y70R	091 NCS S 1010-Y70R	051 NCS S 2050-G30Y
Velour II	001 NCS S 0510-Y30R	090 NCS S 3060-Y90R	023 NCS S 1015-B	012 NCS S 3500N
Sable II	082 NCS S 0515-Y60R	080 NCS S 1060-Y60R	111 NCS S 2030-Y70R	131 NCS S 3010-Y50R
Sable II	131 NCS S 3010-Y50R	080 NCS S 1060-Y60R	111 NCS S 2030-Y70R	060 NCS S 0515-Y30R
Sable II	082 NCS S 0515-Y60R	100 NCS S 4040-R	101 NCS S 3050-R10B	131 NCS S 3010-Y50R
Sable II	131 NCS S 3010-Y50R	100 NCS S 4040-R	101 NCS S 3050-R10B	060 NCS S 0515-Y30R
Sable II	131 NCS S 3010-Y50R	090 NCS S 3060-Y90R	021 NCS S 1030-R80B	060 NCS S 0515-Y30R
Sable I	131 NCS S 3010-Y50R	051 NCS S 2050-G30Y	050 NCS S 4040-G10Y	060 NCS S 0515-Y30R
Sable I	082 NCS S 0515-Y60R	051 NCS S 2050-G30Y	050 NCS S 4040-G10Y	131 NCS S 3010-Y50R
Velour II	013 NCS S 2002-G50Y	053 NCS S 1030-G40Y	051 NCS S 2050-G30Y	001 NCS S 0510-Y30R
Velour II	013 NCS S 2002-G50Y	020 NCS S 3050-R80B	053 NCS S 1030-G40Y	001 NCS S 0510-Y30R
Velour I	013 NCS S 2002-G50Y	021 NCS S 1030-R80B	020 NCS S 3050-R80B	001 NCS S 0510-Y30R
Velour II	013 NCS S 2002-G50Y	021 NCS S 1030-R80B	020 NCS S 3050-R80B	001 NCS S 0510-Y30R
Paysage	052 NCS S 1040-G40Y	091 NCS S 1010-Y70R	001 NCS S 0510-Y30R	051 NCS S 2050-G30Y
Velour I	001 NCS S 0510-Y30R	021 NCS S 1030-R80B	020 NCS S 3050-R80B	012 NCS S 3500N
Velour II	001 NCS S 0510-Y30R	021 NCS S 1030-R80B	020 NCS S 3050-R80B	012 NCS S 3500N
Velour II	001 NCS S 0510-Y30R	053 NCS S 1030-G40Y	051 NCS S 2050-G30Y	012 NCS S 3500N
Velour II	001 NCS S 0510-Y30R	020 NCS S 3050-R80B	053 NCS S 1030-G40Y	012 NCS S 3500N
Mur II	112 NCS S 1015-Y70R	090 NCS S 3060-Y90R	020 NCS S 3050-R80B	122 NCS S 1020-Y60R
Velour II	013 NCS S 2002-G50Y	051 NCS S 2050-G30Y	050 NCS S 4040-G10Y	001 NCS S 0510-Y30R
Velour I	013 NCS S 2002-G50Y	100 NCS S 4040-R	101 NCS S 3050-R10B	001 NCS S 0510-Y30R
Velour I	001 NCS S 0510-Y30R	100 NCS S 4040-R	101 NCS S 3050-R10B	012 NCS S 3500N
Velour II	001 NCS S 0510-Y30R	051 NCS S 2050-G30Y	050 NCS S 4040-G10Y	012 NCS S 3500N
Sable II	082 NCS S 0515-Y60R	101 NCS S 3050-R10B	080 NCS S 1060-Y60R	131 NCS S 3010-Y50R
Sable II	131 NCS S 3010-Y50R	101 NCS S 3050-R10B	080 NCS S 1060-Y60R	060 NCS S 0515-Y30R
Velour II	013 NCS S 2002-G50Y	081 NCS S 1050-Y60R	080 NCS S 1060-Y60R	001 NCS S 0510-Y30R
Velour II	001 NCS S 0510-Y30R	081 NCS S 1050-Y60R	080 NCS S 1060-Y60R	012 NCS S 3500N

TABLE 5 Summary of the findings

Hue		
Fond	Avr_HueFond	Bedrooms are more preferred when the hues of *valeurs de fond* are between 180° and 240° (NCS G to B30G). There is a clear drop in preference when hues are between 300° and 360° (NCS R60B to R)
	Diff_Hue Fond	Bedrooms are more preferred when the hues of *valeurs de fond* have a difference ≤90° (=10 NCS Hue families).
Ton	Avr_HueTons	No significant
	Diff_HueTons	No significant
Total	Dif_Hue_Total	Bedrooms are more preferred when the hue difference is ≤3 NCS Hue families, between the average hue of the two *valeurs de fond* and the average hue of the two *couleurs tons*.
Blackness		
Fond	Avr_BlckFonds	Bedrooms are more preferred when the blackness of *valeurs de fond* is ≤10%
	Diff_BlckFonds	Bedrooms are more preferred when blackness difference between the *valeurs de fond* is ≤20%
Ton	Avr_BlckTons	No significant
	Diff_BlckTons	No significant
Total	Dif_Blck_Total	Bedrooms are more preferred when the blackness difference increases, between the average blackness of the two *valeurs de fond* and the average blackness of the two *couleurs tons*
Chromaticness		
Fond	Avr_Chrm_Fonds	Bedrooms are more preferred when the chromaticness of v*aleurs de fond* are ≤20%
	Diff_Chrm_Fonds	Bedrooms are more preferred when chromaticness difference between *valeurs de fond* decreases
Ton	Avr_Chrm_Tons	Bedrooms are more preferred when the chromaticness of *couleurs tons* decrease
	Diff_Chrm_Tons	Bedrooms are more preferred when chromaticness difference between *couleurs tons* decreases
Total	Diff_Chrm_Total	Bedrooms are more preferred when the chromaticness difference is ≤20%, between the average chromaticness of the two *valeurs de fond* and the average chromaticness of the two *couleurs tons*

Nemcsics, who reported high harmony content in triads of colors with hues in the color wheel that were (a) close to each other, (b) opposite in the color wheel, or (c) with a distance of 120°.[36]

Again, the results about current preference for bedrooms with colors combination criteria based on blackness indicate that the blackness of *valuers de fond* is more significant in preference than the blackness of *couleurs tons*, as we have not found any significant correlation with *couleurs tons*. The bedroom preference increases when the average blackness of *valeurs de fond* is ≤10%, and when the blackness difference between the two *valeurs de fond* is ≤20%. Therefore, actual observers seem to prefer interiors with *valeurs de fond* with low blackness and low blackness contrast. These findings are consistent with those by Ou and Luo who found that the most harmonic color pairs are those with a high lightness value.[17] Nevertheless, in our experiment, current observers are in favor of a certain blackness contrast between the average blackness of the two valeurs *de fond* and the average blackness of the two couleurs *tons*. In brief, observers prefer light colors for the backgrounds (with low blackness and with low blackness difference) and certain blackness contrast between these *valeurs de fond* and *couleurs tons*, with independency of the blackness of the *couleurs tons*.

The results about current preference for bedrooms with colors combinations criteria based on chromaticness indicate that preference has significant correlation with the chromaticness of both *valuers de fond* and *couleurs tons*. This finding is consistent with Nemcsics, who found that the harmony content depends on the relative surface coverage of the colors present, particularly for highly saturated colors.[30] In our research, bedrooms are more preferred when the average chromaticness of the two *valeurs de fond* is ≤20%, and when chromaticness difference between the two *valeurs de fond* decreases. So observers preferred two *valeurs de fond* with low chromaticness and low chromaticness difference. In the case of the two *couleurs tons*, preference for the bedroom increases when their chromaticness decreases and their chromaticness difference decreases. Therefore, observers preferred bedrooms containing two *couleurs tons* with low chromaticness and similar chromaticness between them. Moreover, the bedrooms are more preferred when the chromaticness difference is ≤20%, between the average chromaticness of the two *valeurs de fond* and the average chromaticness of the two *couleurs tons*. Therefore, generally speaking, observers like bedrooms containing colors with low chromaticness and similar chromaticness among them.

The results of our findings will provide new perspectives about the best color combination criteria suitable for interior architecture and the applications of the Salubra 1931 color keyboards in contemporary spaces. The results link the NCS attributes hue, blackness, and chromaticness to the preferences for bedrooms by current architecture and design students, and give a deep analysis to the application of the four color combinations set by Le Corbusier's in 1931.

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DATA AVAILABILITY STATEMENT

Data available on request from the authors.

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