

Is a house named “yellow” really yellow? Survey on the perception and naming of the yellow color on building facades depending on its hue, lightness and saturation

Justyna Tarajko-Kowalska

Cracow University of Technology, Faculty of Architecture, Poland, justarajko@tlen.pl

ABSTRACT

The article's primary goal is to present the author's online color survey results. The study was aimed at checking which colors chosen from NCS Color System's four yellowish hue groups: G80Y, G90Y, Y, and Y10R are considered as "yellow." The 28 nuances differed in hue, lightness, and chroma, were presented separately on color swatches and building facades. At first, the respondents assessed the yellowness of selected colors and then indicated the most appropriate ones for the color term "yellow." The analysis of the 444 results confirmed the high importance of saturation and lightness (whiteness/blackness level) in color appearance and naming. The research proved that a given color is likely described as "yellow" only when its parameters of lightness and saturation are similar to the prototype of the yellow color category, characterized by high saturation and high intrinsic lightness. The clarity of the hue was also the significant factor.

KEYWORDS Yellow, Color in architecture, Color attributes, Color naming, Color appearance, Color perception

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1. Introduction

The yellow color has been common in architecture since the earliest times. For ages the rationale and ways for using this hue in built environment were diverse, but it was always present in many varieties due to its positive connotations with sun, light and metal gold, as well as the popularity and availability of ochre pigments. Yellow ochre was not only the oldest yellow pigment but also one of the first pigments ever used by humans. Thus, warm, orangey yellows were and still are shaping the chromatic perception of many towns and villages around the world. In contemporary built environment, yellow plays an important role in the city visual communication system and corporate identity, being also common color of mailboxes, taxis and tramways. Thanks to new materials and technologies, highly saturated yellow as a visual attractor appears both in public buildings and spaces, being modern and an intriguing color in architecture (Tarajko-Kowalska 2021). Many research confirms (e.g. Janssens and Küller, 2009), that yellowish hues from groups: YR (yellow-red), Y (yellow), and GY (green-yellow), according to the NCS – Natural Color System nomenclature, are constantly most preferable for residential buildings facades in many countries, especially in Europe. But, compared to the other primary colors, pure yellow occurs only in a narrow band of the spectrum with a wavelength of 570–580 nm (Lancaster, 1996). Varieties of yellow may differ in one, two, or three of the color attributes: hue, lightness and saturation (chroma), thus creating a full spectrum of tones and shades. In the environment many yellowish tones exist, as it "*can tend toward green on the one hand and toward orange on the other*", being described as color of gold, lemon, sulphur and saffron (Pastoreau, 2019). This richness of nuances can be represented for example by Latin vocabulary, where the most frequently used adjective *flavus* describes saturated yellow, while *fulvus* means darker yellow, *croceus* - saffron orangish yellow, *luteus* is used for ordinary yellows present in flora and fauna, *aureus* represents gold, *luridus* grayish yellow etc. (Pastoreau, 2019).

In residential architecture yellows are usually used in pastel tones with high lightness level, in muted shades with low chroma, or as earthy browns. So the question arises: is a house colored yellow really perceived as yellow? Because in most cases very dark or very pale tones cease to appear yellow anymore. Also, the latest studies on color-emotion relations confirm that less saturated and darker yellows do not even produce the same emotional reactions as highly saturated ones (e.g. Schloss *et al.*, 2020). The same conclusion comes from the author's recent study on the use of the yellow color in architecture and built environment, where only those

examples in which highly saturated tones were used, seem to carry all the characteristics and associations assigned to the yellow color, considering its symbolic, functional, and decorative aspects (Tarajko-Kowalska, 2021). While thinking or reading about the "yellow building", don't we imagine a brightly colored house, clearly visible in the landscape or being a visual attraction in public space? Those findings and questions led the author to research which samples and building facades, colored in yellowish hues, different in the attributes of lightness and saturation, are still considered as "yellow". The main purpose of the article is to present the results of this color survey [1].

2. Method

To conduct the research, an online questionnaire was prepared in Google Forms. The main reason for choosing this form of survey was the author's desire to obtain as many results as possible, with participants' minimal workload. The study was also meant to be entertaining for participants so that the responses obtained were not forced but reflected the real observers' opinions.

2.1 Survey structure

The study consisted of three parts. The first part was dedicated to collect the respondents' data. Participants reported their gender (female/male) and age (<18, 18-29, 30-39, 40-49, 50-60, >60). They were also asked to specify the level of their experience with color (none, basic, middle, or advanced) and give the information if their proper color vision was confirmed by a medical examination for driving license and/or any color tests. It was also possible to make quick tests online while filling the survey, by clicking the given links to the Ishihara test (<http://colorvisiontesting.com/ishihara.htm>) and X-rite test (<https://www.xrite.com/hue-test>).

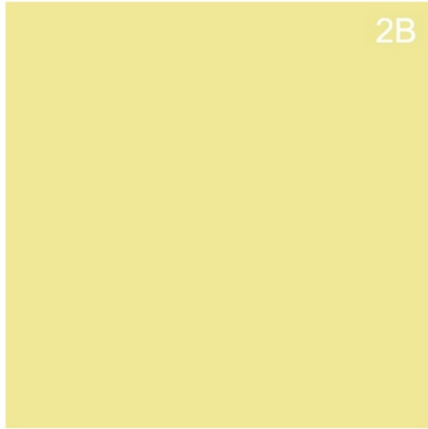
In the second part, participants were rating on a scale from 1 to 5 (1 – definitely not, 2 – rather not, 3 – not sure, 4 – rather yes, 5 – definitely yes) if randomly presented color samples can be considered "yellow" (Figure 1). After that, responders were asked to indicate three color samples (from all twenty eight color samples seen before) they think are most adequate for the color term "yellow".

The third part of the study was dedicated to building facades (Figure 2). Similarly to previous part, the respondents were asked at first to rate on a scale from 1 to 5 the level of "yellowness" of the presented building façade, which was computer-painted in one of the twenty eight selected colors - same as color swatches seen before. After finishing, they chose three facades, which

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colors they consider the most appropriate for the term "yellow". On average, to complete the survey took around 10-15 minutes.

2B Czy uważasz, że prezentowana próbka barwna może być uznana na „żółtą”? / Do you think that the presented color sample can be considered "yellow"?



1 2 3 4 5

zdecydowanie nie / definitely not zdecydowanie tak / definitely yes

Fig. 1. General appearance of the questionnaire for color sample (question: Do you think, that the presented color sample can be considered "yellow"?)

2B Czy uważasz, że prezentowana elewacja może być uznana na „żółtą”? / Do you think that the presented building facade can be considered "yellow"?



1 2 3 4 5

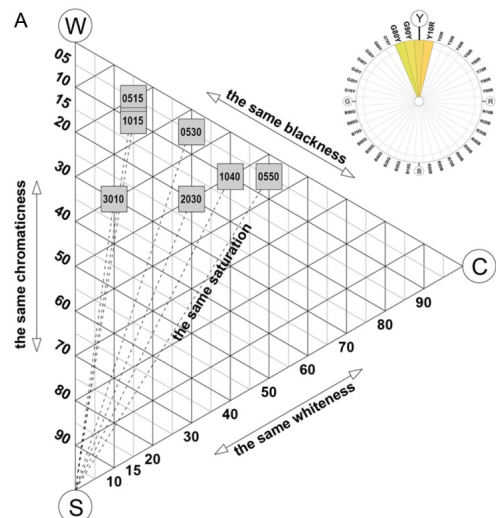
zdecydowanie nie / definitely not zdecydowanie tak / definitely yes

Fig. 2. General appearance of the questionnaire for building façade (question: Do you think, that the presented building facade can be considered "yellow"?)

2.2 Colors selection

In order to conduct the survey, 28 colors, differing in hue, lightness (whiteness/blackness level) and saturation (chromaticness), were specified, then used to color the samples and facade of the selected building. The colors used in the survey have been chosen from NCS Color System's four yellowish color groups: G80Y, G90Y, Y, and Y10R. The Y20R group was also considered, but due to strong orange appearance of the nuances it was finally rejected in favour of the G80Y group.

Authors' wish was to represent all the color families: pastel (high lightness and chroma), pale (high lightness and low chroma), vivid (highly saturated), rich (low lightness and high chroma) and finally dull (low lightness and low chroma). However, due to the fact that selected colors were to be presented also on the building façade, very dark and highly saturated colors have been eliminated from the list. Another limiting element was the number of samples for presentation. Finally, seven nuances were selected from each hue group to represent the colors that often appear on the facades of residential buildings: 0515, 0530, 0550, 1015, 1040, 2030, 3010. The author made the choice based on her experience as an architect-designer and on the knowledge of the color palettes offered by various manufacturers of facade paints and plasters. The NCS triangle was used to provide the same nuance for samples from particular hues (Figure 3).



B

nuance (aabb)	w	s	v	c	m
0515	80	05	0,95	15	0,16
0530	65	05	0,95	30	0,31
0550	45	05	0,95	50	0,52
1015	75	10	0,9	15	0,17
1040	50	10	0,9	40	0,44
2030	50	20	0,8	30	0,37
3010	60	30	0,7	10	0,14

Fig. 3. Selection of the colors to the survey; A. NCS triangle with position of the 7 selected nuances and NCS circle with selected hue groups: G80Y, G90Y, Y, Y10R;

B. Table with selected nuances and their parameters: *s* - blackness (*aa*), *c* - chromaticness (*bb*), *w* – whiteness, *v* – lightness, *m* – saturation.

As the color samples were to be presented online, to reflect the colors of a specific notation, the NCS Colourpin Application was used, which ensures a high degree of compatibility between the appearance of the physical NCS Colour samples and the one presented on the displays of electronic devices. Of course, the author realizes that in the case of patches showed online accurate color presentation cannot be fully ensured. However, in the case of the conducted research, the perfect match of the appearance between the physical samples and the one visible on the screen was not the highest priority and in the author's opinion it did not significantly affect the obtained results.

2.3. Building selection

For the rating of “yellowness” level of the facades, Njálsgata House in Reykjavik on Iceland was chosen (Figure 4). This residential building from early 20th century undergone in 2015 contemporary refurbishment and reorganisation by Krads architects (<https://www.archdaily.com/923370/njalsgata-house-krads>). The building was selected mostly because its form and style can easily accept different shades and tones of yellowish hues. The house has also gray roof and neutral, almost achromatic neighborhood, which reduced possible influence of adjacent chromatic colors on the perception. For the same reason the photo was taken on a cloudy day, to avoid sun contrasts and shades, which could affect final color appearance.



Fig.4. Façade of Njálsgata House in Reykjavik on Iceland selected for the presentation of colors in survey.

3. Results

The results of the study were presented and analyzed in two ways. The first part consists of the outcomes of “the yellowness” assessment of the individual 28 colors. Those results were presented in individual column charts for each of the 28 swatches and facades, generated automatically in Google Forms, and then the summary graphs for each hue group (G80Y, G90Y, Y, Y10R) were created by author. The second part contains the results of the color selection most appropriate for the term “yellow.” These effects were presented as horizontal bar charts (also generated in Google Forms Program) ranked from the nuances most frequently chosen to those with the slightest indications.[2]

3.1 Participants

The author collected the data presented in this article in May 2021 for around one month. During that period, 444 participants took part in it, 332 females (74,9%) and 112 males (25,1%). They were primarily Polish students and academic teachers from the Cracow University of Technology, Faculty of Architecture, but also students of Industrial Design from the Cracow Academy of Fine Arts and others. More than half were in the age range 18-29 (53,3%). Next age group was 40-49 and 30-39 range with about 16% each. There were also some participants in the age range 50-60 (8%) and over 60 (4,7%), as well as few in age less than 18 (1,3%). Only 21% of the participants do not have any confirmation for their proper color vision besides their declarations. Most of the respondents (90,4%) declared some experience with color (basic – 28,1%, middle – 38%, advanced-24,3%). Detailed participants data are presented in Table 1.

Total number of participants		444				
Gender		Female - 332		Male - 112		
Age range						
<18	18-29	30-39	40-49	50-60	>60	
6	237	70	75	35	21	
Experience in work with color						
none		basic		middle		advanced
43		125		168		108
Confirmation of proper color vision						
not confirmed					95	
medical test for driving license					297	
Ishihara's test					82	
X-rite test					66	
other					33	

Table 1. Survey participants statistics data

3.2 Results of part I – The assessment of yellowness of individual colors appearance on swatches and building facades

In the rating if presented color can be considered "yellow" (at first assessed on swatches, then on facades), the highest unanimity and percentage of "yes" responses (percentage shown together for answers 5 - "definitely yes" and 4 - "rather yes") was achieved by the nuance 0550 (highest saturation/lightness, lowest whiteness). The undisputed number one became color 0550-Y with the "yes" results equal 96.2% for sample and 98.2% for facade. The colors 0550-G90Y and 0550-Y10R achieved only slightly worse results, with the percentage of "yes" indications consistently higher for the facades (93,9%, 91,2%) than for the swatches (83,8%, 84,2%). For the 0550-G80Y nuance, a high level of the consensus occurred only for the elevation (82% to "yes"), while for sample over 50% of the responses were negative.

The highest percentage of "no" responses concerns the nuance 3010 (lowest saturation/lightness, highest blackness), which for all hues was not perceived as yellow either for the color swatches or the facades in more than 90% (in most cases, the percentage of the summed up answers 2 - "rather no" and 1 - "definitely not" reached 98.9% for samples and 95% for facades).

Also for the 1015 nuance (low saturation, high whiteness), the negative responses dominated in the case of samples, changing slightly together with the hue from G80Y to Y10R (97.1% - 74.1% - 75.8% - 80.8%). In the case of facades, the responses were very diverse, except for the hue G80Y with 72% to "no." There was a slight "yes" tendency for hues G90Y and Y (53.5% -49.2%), but for Y10R the numbers of "yes" and "no" responses were nearly even.

The nuance of 2030 (average level of saturation/lightness, lowest whiteness) brought interesting results, as it existed a discrepancy in its perception between swatches and facades. There was a high percentage of the "no" answers for the samples, slowly decreasing while changing the hue (94.5% -93.5% -85.3% -77.2%). In the case of the facades, the situation was different. While for greenish yellows G80Y and G90Y, the percentage of negative responses was still significant (71.6% -52.3%), for hues Y and Y10R there were more responses to "yes" (51.9% - 68.2%).

In the case of the 1040 nuance (high saturation, average blackness/lightness), the hue also played a significant role. Only for the Y there was a high "yes" percentage for both the samples (81%) and the facades (97%). Y10R hue has still high "yes" responsiveness for facades (80%), while for samples it was only 60%. For the greenish yellows of G90Y, there was still a high percentage of "yes" responses to facades (74%), but "no" responses began to dominate

in the swatches (42.5%). For the G80Y, the "no" responses predominate for both the samples (80%) and the facades, although here to a lesser extent (60%).

In the case of the 0530 nuance (highest lightness, middle saturation, lowest blackness), full agreement of the "yes" responses occurred for the hues G90Y and Y, with a higher percentage observed for the facades (96%, 92%) than for the samples (77%, 72%). At the Y10R hue, a large variation in the results for the swatches was observed, together with a slight dominance of the "yes" answers for the facades (60.5%). For the G80Y, there was a full discrepancy in the responses, with 65% "no" for the samples and 58% "yes" for the facades.

For the 0515 nuance (highest lightness/whiteness, low saturation), there was also a dissimilarity of opinions between the samples and facades assessment. Here, too, the hue played a decisive role. For the swatches, the responses were mostly negative, with the percentage of "no" gradually decreasing with the hue change from G80Y to Y10R (89%-69% -50.4% -49%). For the facades, with the change of the hue, the number of positive responses increased from 49% to "no" for the G80Y to 61% to "yes" for the shade Y10R.

Detailed results of part I of the survey are presented in Table 2.

hue / nuance		0515		0530		1015		1040		0550		2030		3010		
hue	nuance	C	s	f	s	f	s	f	s	f	s	f	s	f	s	f
		G80Y (%)	1	66,8	26,6	35,9	10,4	85,1	44,9	58,5	34,3	30,7	5,9	81	40,4	94,8
2	22,3		22,6	28,9	14,7	12	27,1	21,7	22,6	21,7	4,1	13,5	31,2	3,6	7,7	
3	7,7		22,8	19,9	17,6	1,8	16,9	10,8	14	19,9	7,2	3,6	14,7	0,0	3,6	
4	2		17,6	10,8	29,8	0,2	6,8	6,8	13,1	16,7	17,6	0,7	8,6	0,5	0,5	
5	1,1		10,4	4,5	27,5	0,9	4,3	2,3	16	11,1	65,2	1,1	5,2	1,1	0,2	
G90Y (%)	1	45,1	11,7	2,9	0,5	42	5,2	19	6,8	2,3	0,7	74,3	27,5	94,6	83,1	
	2	23,9	20,3	6,5	0,2	32,1	16,5	23,5	7,2	5	1,4	19,2	24,8	3,8	10,8	
	3	19,9	23,9	12,9	2,9	14,4	24,8	25,7	12	9	4,1	5	20,3	0,5	5,2	
	4	7,9	24,2	31,4	14,2	8,6	33,4	23,7	24,6	20,1	12,1	0,7	16,9	0,2	0,5	
	5	3,2	19,6	46,3	82,2	2,9	20,1	8,1	49,4	63,7	81,7	0,9	10,4	0,9	0,5	
Y (%)	1	26,2	12,6	3,4	0,2	44,9	6,8	2,3	0,5	0,9	0,5	64,1	9,9	94,6	76,5	
	2	24,2	21	8,6	1,6	30,9	18,1	3,8	0,7	2	0,2	21,2	16,9	4,3	15,6	
	3	24,8	23,3	15,8	5,6	16,7	26	13,1	1,6	0,9	1,1	10,4	21,2	0,0	8,1	
	4	17,8	25,3	37	26,9	6,1	28,2	24,4	12,4	9,5	6,1	3,2	28,4	0,2	0,9	
	5	7	17,8	35,2	65,7	1,4	21	56,4	84,9	86,7	92,1	1,1	23,5	0,9	0,9	
Y10R (%)	1	18,3	2,7	15,8	7	52,6	12	7	2,9	2,5	1,6	49	2,9	93,7	78,8	
	2	30,7	14,7	19,9	13,1	28	24,4	13,1	8,4	5	2,9	28,2	11,1	4,1	12,6	
	3	18,5	21,7	24,2	19,4	13,5	28,2	19,6	9,5	8,4	4,3	10,8	17,8	0,9	7	
	4	21	33	25,1	30	5	21,2	30	24,2	21,9	14,7	9,5	28	0,2	1,1	
	5	11,5	28	15,1	30,5	0,9	14,2	30,2	55,1	62,3	76,5	2,5	40,2	1,1	0,5	

Table 2. Results of part I. Yellow color appearance (perception) on color samples (s) and on building facades (f) in %. 1-definitely not, 2-rather not, 3-not sure, 4-rather yes, 5 -definitely yes.

3.3. Results of part II – The best examples of the yellow color on swatches and building facades

The color 0550-Y was found to be the most appropriate for the term "yellow" for both the swatches (93,4%) and the facades (80.8%). Among the presented samples, it was

the color with the highest level of both saturation and lightness. It also has no admixture of other primary colors (it is neither reddish nor greenish). Thus, it can be treated as a "unique hue" and the most similar color to the typical representative for the yellow color category (see Witzel, 2018, Schloss et al., 2020).

The colors 0550-Y10R (71% for samples and 48.5% for facades) and 0550-G90Y (52.7% for samples and 63% for facades) were second. Also, these colors are characterized by the highest saturation and lightness, but their hues have slight admixtures of red and green, respectively. The remaining color 0550-G80Y in this nuance came in a relatively high fifth place for facades (26.9%), but for the samples, it was in the ninth position with only 4.1% of the response.

The next places were colors: 1040-Y, 0530-Y, and 0530-G90Y. A small percentage of the answers were also given to the nuances 1040 and 0530 for the Y10R hue, and in the case of the facades also for the G80Y. The nuance 3010 was not indicated even once for any of the hues.

Neither for the samples nor the facades were indicated colors having both a high degree of whiteness and low saturation (0515, 1015) or low saturation and low lightness (3010). Thus, saturation was the decisive parameter in that case.

For colors with an average saturation level (0.35, 0.37) lightness and blackness were the decisive parameters. The darker nuance 2030 (brightness 0.8) was not indicated at all, while the lighter 0530 (brightness 0.95) was ranked relatively high for hues Y (28.5% samples) and G90Y (20.5% facades) (see details on Figure 5).

4. Conclusion and discussion

The analysis of the results confirmed, also emphasized by other researchers (e.g., Witzel, 2018, Witzel et al., 2019, Schloss et al., 2020, Divers, 2021), the importance of saturation and lightness (the degree of whiteness/blackness) in colors appearance and naming. The attribute of saturation was the most significant when indicating adequate colors for the term "yellow" (the higher the chroma, the more often the color was chosen). Next, the decisive parameter was the degree of whiteness and blackness - colors with a high blackness or whiteness were rarely indicated as "yellow."

The research proved that a given color is likely described as "yellow" only when its parameters of lightness and saturation are similar to the prototype of the yellow color category, characterized by high saturation and high intrinsic lightness (Schloss et al., 2020). Color appearance is also typically assessed by reference to one of the unique hues (Witzel, 2018). That explains why the most frequently indicated was the purest hue Y, then Y10R and G90Y, and least often G80Y. The clarity of the hue was the decisive factor, especially in the case of both highly saturated and whitened colors. It seems that the confidence of indicating "no" increased with dark and low saturated colors because both parameters are different from the typical yellow prototype mentioned previously. In addition, dark yellows cross the color category from "yellow" to "brown" (Schloss et al., 2020), and the hues of G90Y and G80Y visually turn green.

In the comments to the survey, the respondents assessed the survey as giving "fun" but at the same time causing confusion and raising deep doubts about the nomenclature and definition of colors with variable saturation and lightness, and what can still be called "yellow" and what not. So, there is a need to go beyond the basic color categories in the scientific research, as they do not cover the whole variability of perceived color "subcategories", depended its parameters (in case of yellowish hues this will be, e.g., when lighter: beige, darker: brown, greener: lime, redder: ochre, orange, see Figure 6). This can be achieved by extending (but not replacing) the "hue paradigm" with the "value-chroma paradigm" (see Divers, 2021). This is important particularly in environmental color design as the vast majority of nuances present in natural surroundings are not highly saturated.

The research also reveals that various nuances are more likely declared "yellow" on the façades than on the samples. This is especially evident when the swatches were rated as not yellow while the facades were still placed in the yellow category. It is known that color is perceived differently on the sample than on the facade.

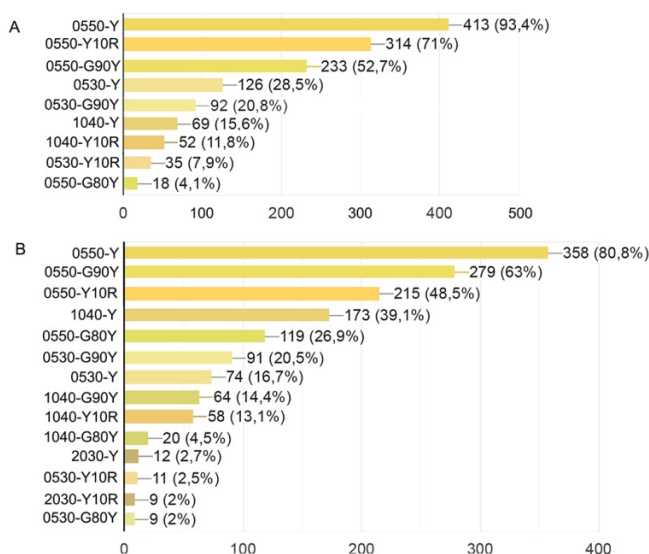


Fig 5. Results of part II - Color swatches and building facades considered as most suitable for term "yellow". Ranking list of top 9 nuances for swatches (A) and 14 (B) nuances for facades.

However, the reason for these discrepancies may also be that the color of the sample is evaluated strongly by reference to the typical yellow prototype. In contrast, for the facade, observers base their judgment more on experience and cultural traditions. Thus, the color tests and color choices, which concern particular objects (such as buildings), should not be performed only on color samples, as they may give completely different, even opposite results.

Those findings may be a starting point for a wider discussion on the actual preferences of yellowish colors for building facades and the way of describing them in the context of not only the hues but also, perhaps even above all, their lightness and saturation.

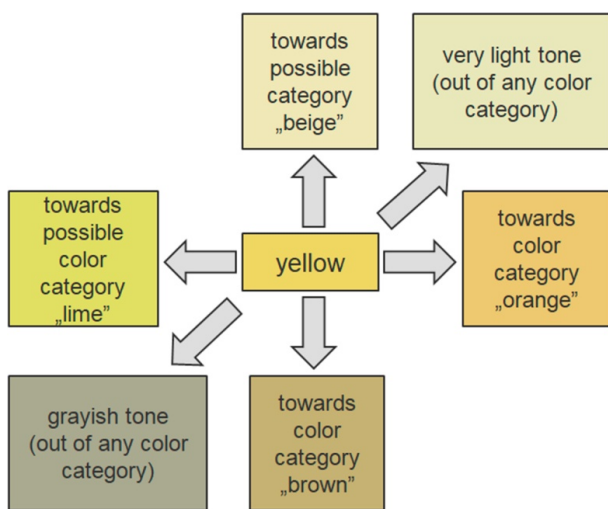


Fig 6. Potential yellow color "subcategories", depended on the parameters of hue, lightness and saturation.

Conflict of interest declaration

The author declares, that nothing has affected her objectivity or independence in the production of this work. There are no actual or potential conflicts of interest, including financial, personal or other relationships with other people or organizations, that could inappropriately influence (or be perceived to influence) this work.

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Short biography of the author

Justyna Tarajko - Kowalska - PhD. Architect, lecturer at the Cracow University of Technology, Faculty of Architecture. Author of over 60 articles on the topic of color in architecture, published in Polish and English. In scientific studies, she concentrates especially on the issue of color in the built environment, as well as the history of color in architecture and space.

Notes

[1] The idea to carry out this survey was born during the author's research on the color yellow in architecture and the built environment, the results of which were presented in the article entitled 'Yellow color in European architecture and built environment: traditions and contemporary application' (Tarajko-Kowalska, 2021). For that reason, presented study is of a more technical nature and the author intentionally does not mention the cultural background of the use of yellow, which was described in detail in the paper mentioned above.

[2] Supplementary data to this article with detailed results of the study presented on diagrams can be found online at: https://drive.google.com/drive/folders/1f5eFCWPU3F_MOAADmP1vvWIDbP0OYbo2?usp=sharing

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