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An online color naming experiment in Russian using Munsell color samples

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Abstract

Russian color naming was explored in a web-based experiment. The purpose was 3-fold: to examine (1) CIELAB coordinates of centroids for 12 Russian basic color terms (BCTs), including 2 Russian terms for "blue", *sinij* "dark blue", and *goluboj* "light blue", and compare these with coordinates for the 11 English BCTs obtained in earlier studies; (2) frequent nonBCTs; and (3) gender differences in color naming. Native Russian speakers participated in the experiment using an unconstrained color-naming method. Each participant named 20 colors, selected from 600 colors densely sampling the Munsell Color Solid. Color names and response times of typing onset were registered. Several deviations between centroids of the Russian and English BCTs were found. The 2 "Russian blues", as expected, divided the BLUE area along the lightness dimension; their centroids deviated from a centroid of English *blue*. Further minor departures were found between centroids of Russian and English counterparts of "brown" and "red". The Russian color inventory confirmed the linguistic refinement of the PURPLE area, with high frequencies of nonBCTs. In addition, Russian speakers revealed elaborated naming strategies and use of a rich inventory of nonBCTs. Elicitation frequencies of the 12 BCTs were comparable for both genders; however, linguistic segmentation of color space, employing a synthetic observer, revealed gender differences in naming colors, with more refined naming of the "warm" colors from females. We conclude that, along with universal perceptual factors, that govern categorical partition of color space, Russian speakers' color naming reflects language-specific factors, supporting the weak relativity hypothesis.

KEYWORDS

centroids, CIELAB, color naming, color space, gender differences, linguistic segmentation, Russian, web-based experiment

1 | INTRODUCTION

According to its color, a visual stimulus is assigned to a certain color category. Identified by a linguistic label (in adult humans), language-specific concepts enable attention to be drawn to certain perceptual attributes of reality. Color names, like other groups of semantically related words, are systems in which one word's position influences the positions of all others.[1–3] The aim of this study was to explore Russian speakers' color term inventory, color-naming strategies and linguistic segmentation of color space; an auxiliary aim was to assess gender differences. Data were collected in an online color naming experiment[4] previously undertaken with English speakers, with the purpose of relating outcomes for the 2 languages and delving deeper into the universal versus language-specific patterns of color naming.

1.1 | Basic color terms: Universalist versus (weak) relativity hypothesis

Berlin and Kay's[5] seminal work introduced the concept of universal basic color terms (BCTs). According to their hypothesis: (1) languages can contain up to 11 BCTs named in English *black, white*, *red, yellow, green, blue, purple, brown, orange, pink,* and *gray*; (2) across languages, basic color categories (BCCs) tend to cluster around certain privileged points in perceptual color space—category best examples, or focal colors; (3) BCTs consistently appear in a given language's color lexicon in a constrained order. In a later model, based on data from the World Color Survey, Kay and Maffi[6] elaborated (4) the evolutionary sequence of color category acquisition, while Kay and Regier[7] in their analysis of the World Color Survey data, concluded that (5) color category boundaries may vary between individual languages.

Within the universalist framework, it is conjectured that the relation between BCCs reflects a partition of color space as a form of meaningful information coding of the visible color gamut, a theoretical view put forward by Jameson and D'Andrade.[8] The development of the BCT inventory in a language is nonarbitrary; the lexical refinement implies adding new color categories that maximize color differences between already existing adjacent BCCs, while minimizing color differences within the emerging contiguous categories.

In contrast to the universalist view, the relativist stance holds that the factors governing categorization are particular to a person's culture. In addition, perception of the world is influenced by the semantic categories of a person's native language, and these categories vary across languages with few constraints—a conjecture known as the Sapir-Whorf hypothesis of linguistic relativity.[9]

In the color domain, currently the weak relativity hypothesis is broadly accepted, a reconciliation of the 2 above-mentioned positions, advocated, for example, by Roberson and associates.[10] According to it, boundaries and focal colors of BCCs can vary cross-linguistically, thus affecting color perception and cognition. The weak relativity hypothesis acknowledges that, in addition to universal perceptual factors that govern partition of colors into categories, linguistic, social, and pragmatic factors also drive cognitive processing of color (for reviews see refs. 11 and 12).

The weak relativity hypothesis accommodates a certain aspect of the Berlin-Kay hypothesis—the emergence of new BCCs, beyond the established 11, that are specific to a certain language. However, in addition to the Berlin-Kay partition hypothesis, it also embraces the alternative view, Levinson's[13] emergence hypothesis, whereby new color terms are added to convey hard-to-name colors that have become salient in a language/culture.

Indeed, in recent years, evidence has been accumulated on the emergence of BCTs beyond the 11 postulated by Berlin and Kay, in particular, linguistic differentiation between light and dark blue in East Slavic and many circum-Mediterranean languages (for a review see ref. 14). Also recently, augmentation of the color inventory was demonstrated for modern British English, with *turquoise* and *lilac* considered as emerging BCTs.[15]

1.2 | Russian inventory of BCTs

In their work, Berlin and Kay[1] noted the possibility that Russian has 2 BCTs for "blue", *goluboj* "light blue", along with *sinij* "blue/dark blue". In the following decades this exception to the universal inventory triggered abundant studies on the "Russian blues"[3,16–19] and, in general, on Russian color nomenclature.[1,3,20–29]

Several findings recurred from both linguistic and psycholinguistic studies:

- *BLUE area*. The 2 Russian terms for "blue" are both basic, with *goluboj* "light blue" being a 12th BCT, not a hyponym of *sinij* "dark blue". Their rankings, between 4 and 6, are high and comparable—with regards to frequency of occurrence in corpus analyses[22] and, in an elicitation task, list frequency and mean list position[16,18]. Psycholinguistic studies further demonstrated that the denotative mappings of the 2 "blue" categories and focal colors are distinct, with *sinij*-naming predominating at low-lightness levels whereas *goluboj* is used for lighter colors[2,17,23,30,31] (for reviews see refs. 32 and 33). The 2 "Russian blues" also reveal a category boundary effect as measured by reaction times in an ABX discrimination task.[19]
- *PURPLE area*. Following Berlin and Kay's[5] work, it is agreed that Russian *fioletovyj* most closely meets the criteria for the BCT for "purple". However, the term has low status among the BCTs and a relatively high degree of inconsistent use[34] probably reflecting its recent entry into the Russian lexicon (18th century). Also, the denotative volume of *fioletovyj* (literally translated "violet") is rather constrained: along with it, the PURPLE area is denoted by several nonbasic highly frequent names. In particular, *sirenevyj* "lilac" and *lilovyj* "mauve" in a way "compete" for the PURPLE slot with other terms such as *malinovyj* "raspberry", *bordovyj* "claret", *višnëvyj* "cherry-colored", and old terms (dating back to the 11th and 14th centuries) *bagrovyj* "crimson", *bagrânyj* "purplish-red", and *purpurnyj* "cardinal red".[2,3,22–24,30,34,35]
- *BROWN area*. The Russian BCT for "brown" is *koričnevyj*.[5] It has a high ranking although lower than that of primary BCTs.[16,18,36] In spite of broad combinability with nouns, usage of *koričnevyj* appears constrained predominantly to collocations with nouns for artifacts.[27] For natural objects, in comparison, its old counterpart *buryj* ('dust

brown') is used.[27] A recent exception is *koričnevyj saxar* "brown sugar", food item that entered the Russian market more than 10 years ago: the imported status of this natural product probably invited *koričnevyj*, a BCT, as translation of the English *brown*. Notably, brown rice, another natural product newcomer to the Russian market, is translated as either *koričnevyj ris,* or *koričnevyj (buryj) ris,* or *buryj (koričnevyj) ris*. The interchangeable terms in the "brown rice" collocations, along with a bi-stable focal color for Russian *koričnevyj* category (see Figure 5 in reference28) likely reflect coexistence of the 2, new (strong) and old (weak), "brown" contenders.

1.3 | Gender differences in color naming

Gender differences in color lexicon have been demonstrated in numerous English-language studies (for recent reviews see refs. 37 and 38). Women possess a more extensive color vocabulary than men.[39–43] Also, in addition to BCTs, women use significantly more elaborate terms, BCT hyponyms such as *scarlet, chartreuse,* or *beige*; more BCT qualifiers related to hue and saturation,[44] and offer many more "fancy" color terms like *emerald green* or *cerise pink*.[40,42,45] In comparison, men tend to use predominantly BCTs accompanied by various modifiers, as well as compound names comprising BCTs.

The richer color vocabulary of females was also observed in some languages in Central Asia[46] and Caucasus,[47] in German,[48] Chinese,[49] Spanish,[50] and recently, in Estonian, Italian and Turkish.[51] To our knowledge, gender differences in Russian color nomenclature have not been explored.

In this study we investigate color naming of Russian speakers using data obtained from a web-based experiment employing an unconstrained color-naming method and a representative Munsell color sample. An outcome is compared with previously published data for English speakers. In addition to analysis of the whole dataset, we also examine differences in color naming between females and males.

2 | METHODS

2.1 | Interface of the web-based color-naming experiment

The experimental procedure consists of 6 steps (see Figure 1). First, observers are asked to adjust their display to RGB settings, and to adjust the brightness in order to make all 21 steps of a gray scale ramp visible. In the second step participants answer questions relating to the lighting conditions, their environment and display properties. Then, in the third step, participants are screened for possible color vision deficiencies with a web-based Dynamic Color Vision Test developed at the City University London.[52] The fourth and main part is the unconstrained color-naming (UCN) task: any color descriptor, either a single word, or a compound, or term(s) with modifiers can be produced to describe each of 20 presented color samples. One color (chosen randomly from the sample) is presented twice to each participant, to assess consistency of the participant's responses. Along with the color name typed on a keyboard, response times (RTs) of onset of typing are recorded, defined as the interval between presentation of the color stimulus and the first keystroke. In the fifth step information about the participant's residency, nationality, language proficiency, educational level, age, gender, and color experience is collected. In the final step participants are provided with a summary of their responses and a "Communication Form" for comments.

2.2 | Color stimuli

The color-naming experiment makes use of distributed psychophysics and each participant was presented with a sequence of 20 colors randomly selected from the total of 600 samples in the Munsell Renotation Dataset. Following the suggestions of Billmeyer (cited in reference 53), the 600 samples were chosen as an approximately uniformly distributed array from a variable number of hues at different Munsell Value and Chroma (see Figure 2). The color stimuli were specified in the sRGB color space and out of gamut colors were removed. The Munsell system used in the online experiment was designed with the objective of representing perceptually uniform Hue, Chroma, and Value spacing.[54]

The color stimulus size was 147×94 pixels; it was presented against a neutral gray of $L^* = 51$. Across all observers, each color sample was presented on average 26.2 times (SD = 5.37). Detailed specification of the experimental procedure and color stimuli can be found in reference.[4]

2.3 | Data analysis

The raw dataset included responses from 865 Russian speakers. However, for further analysis only responses were considered from residents of Russia with normal color vision (90.71%), aged 16 years or older, who entered their responses using the Cyrillic alphabet. We also excluded incomplete responses, vernacular acronyms, numerical terms and color terms written in the Cyrillic alphabet but nonRussian (eg, Ukrainian). This filtering resulted in a dataset for 713 respondents, 380 females and 333 males.

In the obtained lists, spelling errors were regularized: Words that were hyphenated, comma-separated, or contained parts in parentheses were treated as multiword color expressions. Different word orders were considered as different names. In the following Russian color terms are given in English transliteration; in English glosses we were

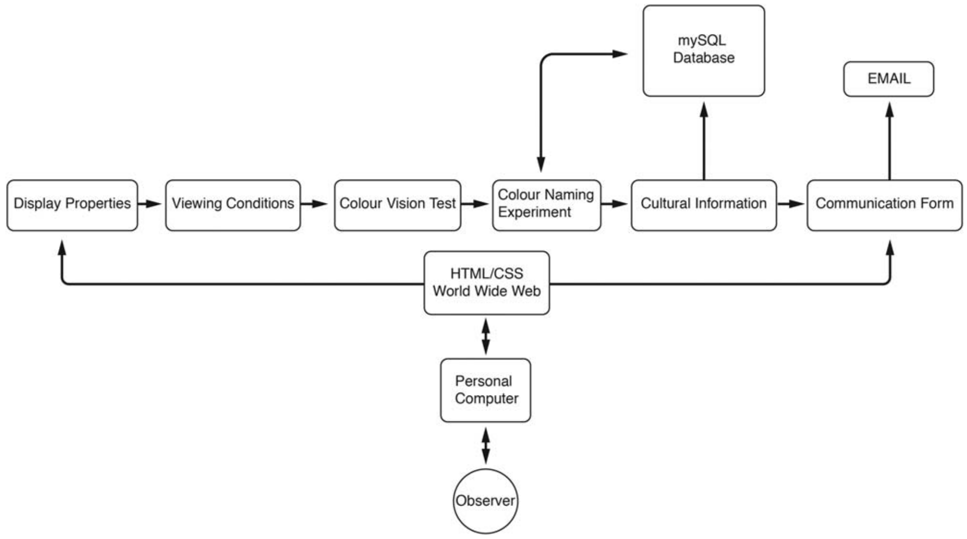

FIGURE 1 Schematic diagram of the web-based color-naming experiment

guided by Frumkina and Mikhejev[20] and Davies and Corbett.[18]

In the following analysis we focused on 3 aspects: (1) centroids for 12 Russian BCTs compared with those for 11 English BCTs; (2) frequent Russian nonBCTs; (3) gender differences in Russian-speaking respondents. Centroids for each color category were calculated by averaging CIELAB co-ordinates of all color samples under the same name; these were obtained for the whole participant sample and gender-split samples. In addition, centroids for Russian BCTs were compared with English BCTs obtained in our previous study.[38]

Gender-split samples were assessed using several parameters: number of unique color descriptors; number of occurrences of BCTs and monolexemic nonBCTs; consistency of color naming; RTs for BCTs and most frequent nonBCTs; lexical segmentation of color space synthetic image visualizing most frequently used color names.

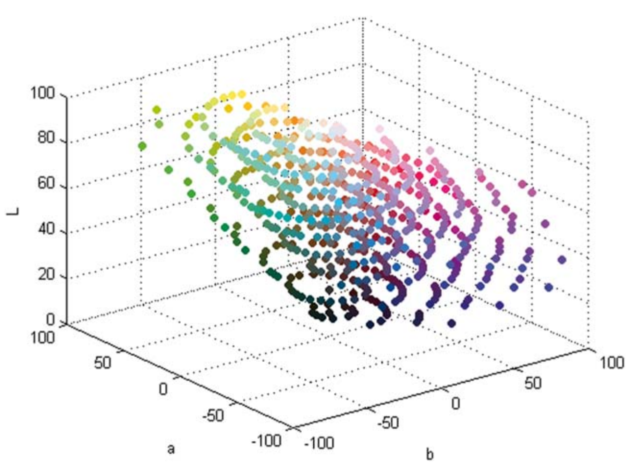

FIGURE 2 Color stimulus set (in CIELAB) used in the online experiment

3 | RESULTS

3.1 | Comparison of centroids for 12 Russian BCTs and 11 English BCTs

We compared location of centroids for 12 Russian BCTs estimated in this study with the centroids for 11 English BCTs obtained under controlled laboratory conditions[53] and in a web-based experiment,[38] the latter having employed the present set of color stimuli and design. Table 1 provides CIELAB coordinates of centroids for the 12 Russian BCTs and 11 English BCTs, along with color differences, ΔE^*_{ab}, between centroid locations of the BCT counterparts in the 2 languages. The data are visualized in Figure 3, in projection on the CIELAB chromatic plane a^*b^* (Figure 3 top) and in 3D explicating centroid location along the lightness axis L^* (Figure 3 bottom).

Both Table 1 and Figure 3 indicate good correspondence between the 3 sets of data. Several discrepancies are noteworthy. These may originate from different sources, reflecting genuine cross-language differences or else differences in methodology, such as color presentation media, color-naming method or (non)uniformity of stimulus distribution in the sample gamut (pointed out by a reviewer).

- Centroids for the 2 "Russian blues" deviate from that of English *blue*, obtained both in the lab-based and web-based experiments. As expected (cf. references[2,17,23,30–33]), *goluboj* is lighter and *sinij* is darker than centroids for *blue* (Figure 3 bottom). In the web-based experiment, also with regards to hue, the centroid for *blue* takes an intermediate position between those for the 2 "Russian blues", where *goluboj*-centroid is more "greenish" and *sinij*-centroid is more "reddish" (Figure 3 top). In comparison, the *blue*-centroid (of surface colors) in the lab-based experiment is more likely to be named *goluboj* by Russian speakers, as prompted by proximity of the 2 respective centroids.

TABLE 1 $L^*a^*b^*$ coordinates for the Russian (R) BCTs ($n = 12$) and the English (E) BCTs (n = 11) in the lab-based study (Sturges and Whitfield; S&W)[53] and web-based study (Mylonas et al.),[55] as well as color differences (ΔE^*_{ab}; CIELAB) between the location of centroids

Russian				English				
Web-based [this study]				**Lab-based [S&W]**				
BCT	L^*	a^*	b^*	**BCT**	L^*	a^*	b^*	ΔE^*_{ab} **R vs. E**
belyj	89.83	0.18	1.51	*white*	88.35	4.68	−4.95	8.0
čërnyj	10.57	−0.21	−2.01	*black*	18.76	1.61	−1.66	8.4
krasnyj	45.49	57.79	32.21	*red*	40.28	52.62	26.48	9.3
žëltyj	81.01	−7.32	66.07	*yellow*	79.99	6.01	69.42	13.8
zelënyj	54.76	−34.51	27.81	*green*	55.14	−35.25	20.11	7.7
sinij	34.48	23.67	−48.19	*blue*	50.24	−10.07	−31.15	40.9
koričnevyj	34.88	16.35	25.95	*brown*	44.55	15.97	31.64	11.2
fioletovyj	35.82	42.16	−36.11	*purple*	43.09	28.27	−28.37	17.5
rozovyj	61.73	50.12	−8.30	*pink*	63.09	38.89	8.98	20.7
oranževyj	63.02	32.86	52.91	*orange*	63.79	35.48	55.05	3.5
seryj	55.07	1.23	−3.00	*gray*	60.70	3.43	−3.62	6.1
goluboj	66.98	−11.38	−24.97	*blue*	50.24	−10.07	−31.15	17.9
Web-based [this study]				**Web-based [Mylonas et al.]**				
belyj	89.83	0.18	1.51	*white*	88.34	3.19	−2.39	5.15
čërnyj	10.57	−0.21	−2.01	*black*	11.15	4.36	−0.90	4.73
krasnyj	45.49	57.79	32.21	*red*	45.03	53.02	31.50	4.84
žëltyj	81.01	−7.32	66.07	*yellow*	81.55	−6.02	62.90	3.47
zelënyj	54.76	−34.51	27.81	*green*	57.18	−33.01	25.96	3.40
sinij	34.48	23.67	−48.19	*blue*	46.77	13.15	−42.30	17.22
koričnevyj	34.88	16.35	25.95	*brown*	33.76	16.21	24.61	1.75
fioletovyj	35.82	42.16	−36.11	*purple*	35.99	41.75	−36.34	0.50
rozovyj	61.73	50.12	−8.30	*pink*	63.52	48.06	−12.05	4.63
oranževyj	63.02	32.86	52.91	*orange*	61.16	33.28	48.67	4.64
seryj	55.07	1.23	−3.00	*gray*	55.86	1.37	−2.59	0.90
goluboj	66.98	−11.38	−24.97	*blue*	46.77	13.15	−42.30	36.20

- Centroids of *yellow* and *žëltyj* obtained in the web-based experiment in English and Russian, respectively, are very close; both, however, are "greenish" deviating from *yellow* centroid obtained in reference 53 for surface colors, a discrepancy that might be due to differences in sampling of the GREEN and YELLOW areas by the 2 stimulus sets.
- Location of centroids for Russian and English counterparts of "red", "purple", "pink", and "brown" obtained in the web-based experiments are similar. Note though that centroids for "purple" and "pink" estimated in the web-based Russian and English studies are both "redder" and "bluer" than the counterpart English centroids in the lab-based study.[53]

3.2 | Centroids for 12 Russian BCTs: females versus males

Figure 4 indicates a very good correspondence between centroids for the 12 Russian BCTs for females and males. Table 2

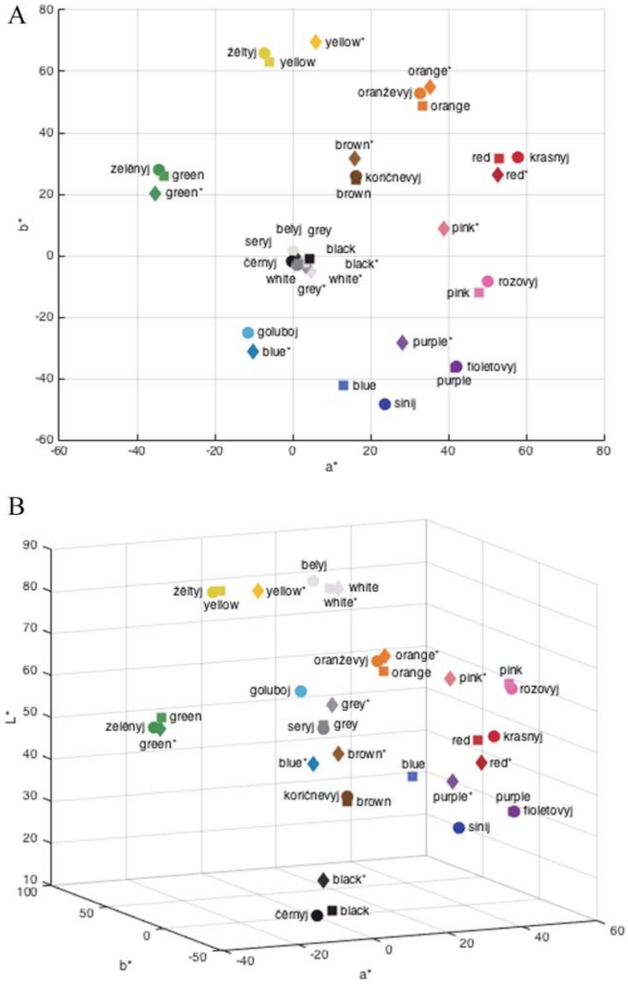

FIGURE 3 Location of centroids for the 12 Russian BCTs (filled circle) compared with centroids for the 11 English BCTs, lab-based (filled diamond) and web-based data (filled square)[38]; *a*b** plane (top) and *L*a*b** presentation (bottom) in CIELAB

presents inter-gender differences for the Russian sample, assessed by a distance for each pair of the BCT centroids in 3D CIELAB (ΔE^*_{ab}). In addition, BCT centroids for the total Russian sample are related to those obtained in the web-based experiment for English speakers.[55] Note that centroids for *goluboj* and *sinij* were related to that for English *blue*. Inter-gender differences for the English sample are presented too.[38]

Mean centroid difference between Russian speakers of 2 genders, $\Delta E^*_{ab} = 3.35$, is small and lower than between English females and males, $\Delta E^*_{ab} = 6.25$[38] (Table 2). Among individual Russian BCTs, the highest inter-gender agreement was for *seryj* ($\Delta E^*_{ab} = 0.68$) and *goluboj* ($\Delta E^*_{ab} = 1.34$), whereas the lowest was for *sinij* ($\Delta E^*_{ab} = 7.02$), *zelёnyj* ($\Delta E^*_{ab} = 6.12$) and *krasnyj* ($\Delta E^*_{ab} = 5.45$).

3.3 | Number of words in color descriptors: total and gender-split samples

For the total sample of Russian respondents ($n = 713$), the refined dataset consisted of 14,260 responses and contained 1422 unique color descriptors. The latter number is comparable to the 1226 obtained in the English-language web-based experiment.[38] Occurrence of color descriptors with varying word number was as follows: BCTs 39%; monolexemic nonBCTs 25%; color terms with one modifier or double-compound terms 33%; color descriptors containing ≥ 3 words 3%. The corresponding numbers in the English naming experiment were 29%, 23%, 42%, and 6%, respectively.[38]

The Russian respondents' dataset was further analyzed with regards to gender differences in color naming. Females showed a richer color vocabulary with regards to the number of unique color descriptors, $n_F = 934$ (66%), compared with males, $n_M = 807$ (57%). Notably, males produced proportionally more BCTs (Figure 5); conversely, females offered more monolexemic nonBCTs than males, in accordance with previous findings for English speakers.[37,38,40,42,45]

Russian speakers of both genders readily used compound (double or triple) color terms, such as *žёlto-zelёnyj* "yellow-green" or *sinevato-fioletovyj* "bluish-purple", as well as color terms specified by achromatic modifiers, such as *bledno-* "pale," *svetlo-* "light," *jarko-* "bright," *tёmno-* "dark", *tusklo-* "dull", *nežno-* "tender" or *grâzno-* "dirty" (cf. references[23,28]). However, usage frequency of polylexemic color names in the Russian gender-split samples (F: 37%, M: 35%) is lower than in English gender-split samples (45% and 49%, respectively).

As prompted by Figure 5, lower proportion of polylexemic terms is complemented by higher proportion of monolexemic (basic and nonbasic) terms offered by Russian respondents: 63% for females and 65% for males, compared with those for English, where the gender-split was 55% and 51%, respectively.

3.4 | Frequent Russian color names: females versus males

The first 10 most frequent color names are identical for Russian females and males, although the ranking order differed slightly (Figure 6). Along with 8 BCTs, these frequent names included 2 nonBCTs, *sirenevyj* "lilac" and *birûzovyj* "turquoise", which occurred in the 7th and 9th positions for females and 10th and 9th, respectively, for males. The high ranking of *birûzovyj* is similar to that of *turquoise* for UK speakers, 8th and 9th for females and males, respectively (reference 38, Figure 4) or its close counterpart *teal* for US speakers, 13th (reference 37, Figure 2). Note that responses to repeated color samples were excluded from the frequency analysis (see consistency analysis).

The repertory of the other most frequent color names (ranks 11–26) demonstrates noticeable gender differences (Figure 6). *Krasnyj* "red" was significantly more frequent in men's lexicon (rank 11) than in women's (rank 26) ($\chi^2 = 18.8$, $P < .001$). Furthermore, 4 nonBCTs in women's lexicon, *beževyj* "beige" (rank 17), *persikovyj* "peach" (rank 20), *bolotnyj* "marsh-colored" (rank 21), and *svetlo-fioletovyj*

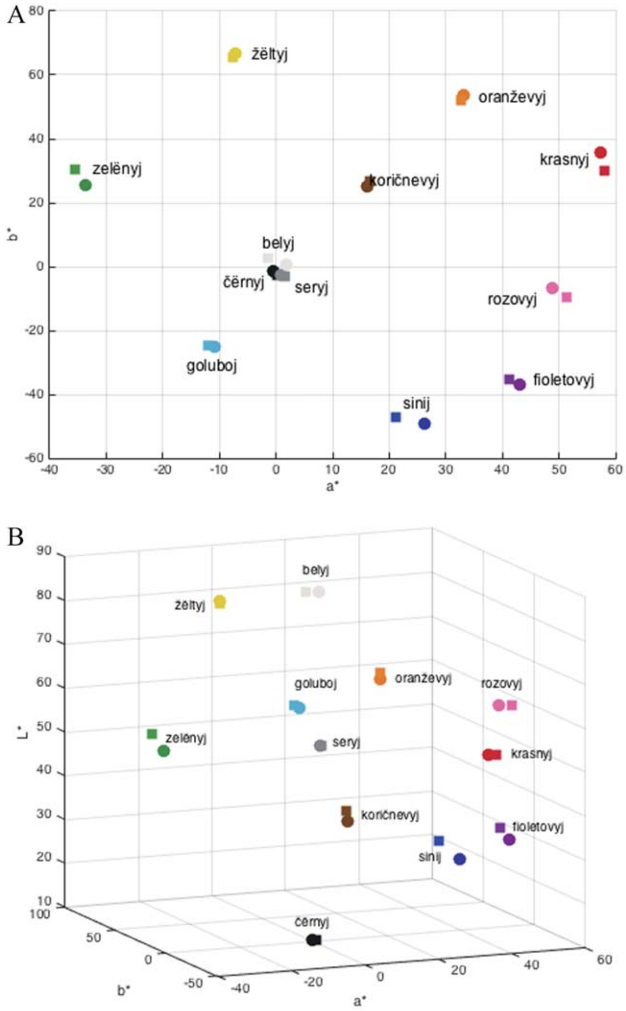

FIGURE 4 Location of centroids for the 12 Russian BCTs for females (filled circle) and males (filled square); *a*b** plane (top) and *L*a*b** (bottom) in CIELAB

"light purple" (rank 24), were not among the most frequent terms used by men. Conversely, 4 terms, *purpurnyj* "cardinal red", *svetlo-koričnevyj* "light brown", *bledno-rozovyj* "pale pink", *tëmno-rozovyj* "dark pink", were high in frequency for men (ranks 20, 22, 25, and 26, respectively), but did not occur among women's frequent names.

It is also worth noting that the list of 26 most frequent color terms offered by Russian speakers includes several terms with achromatic modifiers *svetlo-* "light", *tëmno-* "dark", or *bledno-* "pale". The number of such compounds (F: 6, M: 8) is higher compared with *light-* or *dark*-modified frequent terms of English speakers (F: 4, M: 5) used in combination with *blue*, *green,* or *purple* (reference 38, Figure 4).

3.5 | Occurrence of the 12 Russian BCTs: females versus males

Regardless of the absence of any color-naming constraints, unmodified basic terms were produced very often. Overall

TABLE 2 Mean color differences (ΔE^*_{ab}; 3D CIELAB) between location of centroids for the 12 Russian (R) BCTs and 11 English (E) BCTs,[55] for the total samples and the corresponding gender-split samples

BCT	R vs. E	E_F vs. E_M	R_F vs. R_M
belyj—white	5.15	6.93	3.81
čërnyj—black	4.73	2.29	1.44
krasnyj—red	4.84	20.56	5.45
žëltyj—yellow	3.47	4.99	1.58
zelënyj—green	3.40	3.70	6.12
sinij—blue	17.22	7.82	7.02
koričnevyj—brown	1.75	4.71	2.97
fioletovyj—purple	0.50	2.14	3.68
rozovyj—pink	4.63	6.21	3.92
oranževyj—orange	4.64	7.29	2.15
seryj—gray	0.90	2.17	0.68
goluboj—blue	36.20	...	1.34
Mean 11 BCTs	4.66	6.25	3.53
Mean 12 BCTs	7.29	...	3.35

the frequency of occurrence of the 12 BCTs was significantly greater for men than for women (see Figure 7): $n_M = 2658$ (42%) versus $n_F = 2615$ (36%) ($\chi^2 = 47.5$, $P < .001$; Yate's

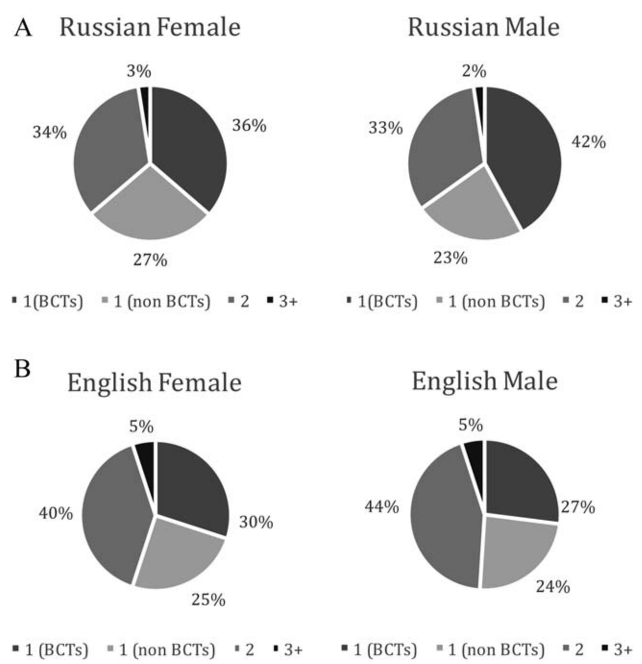

FIGURE 5 Percentage of color descriptors with varying number of words in responses of Russian females and males (top) compared with gender-split responses of English speakers (bottom).[38]

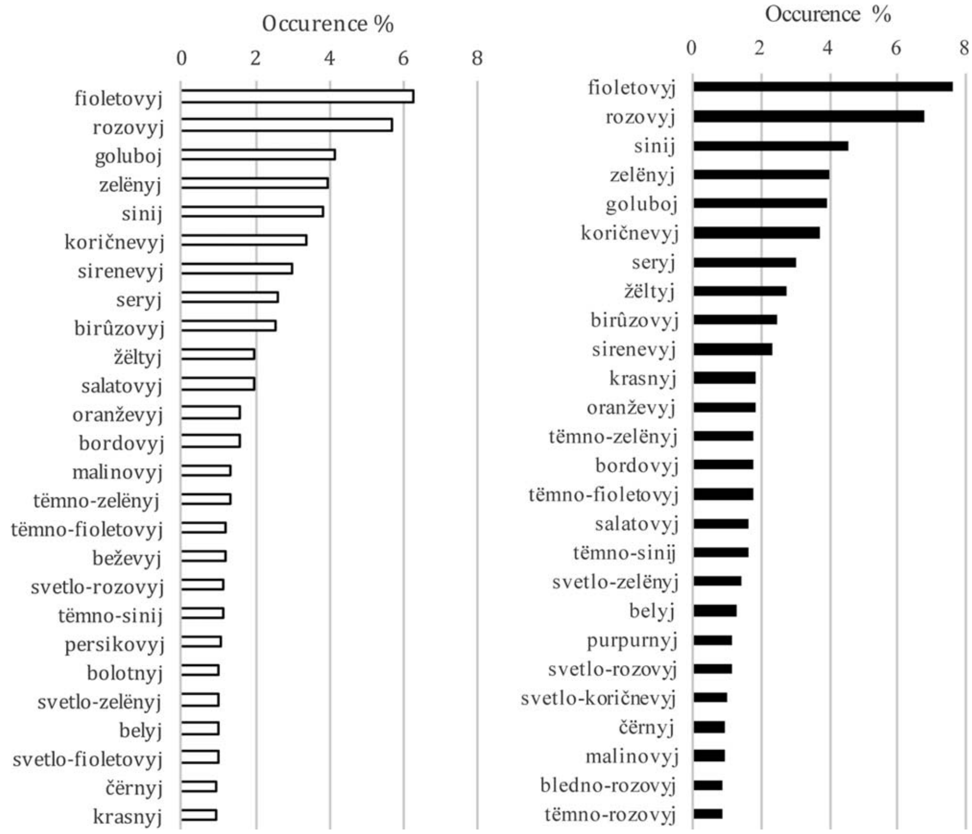

FIGURE 6 Percentage of occurrence of 26 most frequent Russian color names elicited in females (left) and males (right)

correction), but the pattern of relative usage of individual BCTs was similar for both genders. The achromatic BCTs *čёrnyj* "black" and *belyj* "white" had the lowest occurrence, in accord with previous findings (eg. reference 24). The secondary BCTs *fioletovyj* "purple" and *rozovyj* "pink" had the highest total frequencies. This is similar to the outcome of the web-based study of English speakers[38] and appears to reflect the relative prevalence of color stimuli representing the PURPLE area in the Munsell color system.[54]

Furthermore, prompted by the UCN method, beyond the BCTs, respondents produced numerous BCT compounds or multiple combinations of the BCTs with modifiers and object glosses. Women offered 628 (9%) and men 523 (8%) different polylexemic descriptors with BCTs; these were produced using 4 templates (cf. references 27,56,57):

- "basic-basic" (BB), such as *sine-zelёnyj* "blue-green"
- "lightness-modified basic" (LMB), for example, *svetlo-zelёnyj* "light green"
- "hue-modified basic" (HMB), such as *morskoj zelёnyj* "sea green"
- "complex basic" (CB), for example, *jarkij morskoj zelёnyj* "bright sea green".

Table 3 shows derivational productivity of the 12 Russian BCTs, that is, number of unique polylexemic descriptors derived from each BCT and frequency of their occurrence. Notably, a large number of the descriptors reveal attention to lightness differences (LMB) or (diminished) salience of the denoted hue, indicated by the suffix *–ato* "-ish" (eg, *želtovato-kremovyj* "yellowish-creamy"); also, not infrequently a color name is accompanied by an emotionally laden adjective (eg, *âdovito-žёltyj* "poisonous yellow"; *nežno-rozovyj* "tender pink").

As indicated by Table 3, individual BCTs differ markedly in their derivational productivity; this also varies between genders. The great(est) variety of polylexemic descriptors was obtained for *rozovyj* "pink" (F: 436, M: 332), *zelёnyj* "green" (F: 396, M: 397), and *fioletovyj* "purple" (F: 314, M: 313). Big volumes of these BCTs' denotata appear to inspire the use of compounds, modifiers, etc., to convey various shades of the color.

The variety of *rozovyj*-derived descriptors (F: 436, M: 332), apart from a relative overrepresentation of pink stimuli in the Munsell system,[54] points to linguistically marked achromatic differentiation of this area (eg, *ârko-rozovyj nenasyščennyj* "bright pink unsaturated"). In addition, it suggests an implied denotative disambiguation—compare *lavandovyj rozovyj* "lavender pink" and *lososevo-rozovyj* "salmon pink", in line with the finding that Russian speakers' "best exemplars" of the term are split between 2 hues loosely corresponding to English *pink* and *salmon*[28] (Table 1, Figure 2).

The high derivational productivity of *zelёnyj* "green" is hardly of surprise since this category covers the greatest area in

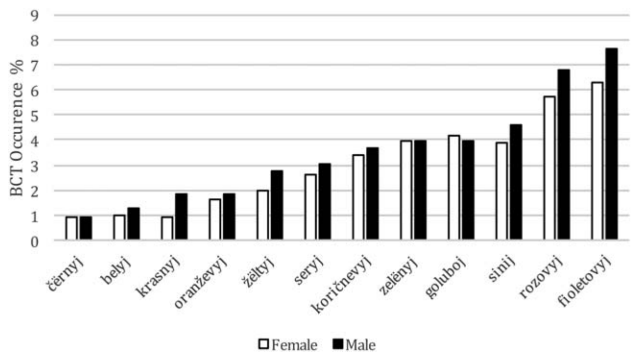

FIGURE 7 Percentage of occurrence of the 12 Russian BCTs for females and males. The BCTs are ordered according to the combined frequency of female and male responses, from lowest (left) to highest (right)

color space, as shown in previous studies for English.[4,37,43,53,57] However, beyond topology, a language-specific factor seems to play a role: Russian naming of the GREEN category is elaborated by frequent use of *zelënyj*-compounds (BB), LMB terms and descriptors containing frequent nonBCTs from this category[23,28] (eg, *salatovo-zelënyj* "lettuce-colored green", *bolotnyj-zelënyj* "marsh-colored green") or alluding to a familiar green shade (eg, *svetoforno-zelënyj* "traffic-lights green", *travânoj zelënyj* "grass green").

Similar types of elaborated color names are also observed in descriptors containing *fioletovyj* "purple": these include highly frequent Russian nonBCTs denoting the PURPLE category addressed in the next section (eg, *sirenevo-fioletovyj* "lilac purple", *bordovo-fioletovyj* "claret purple") and adjectives with references to colors of certain objects (eg, *tëmno-fioletovyj baklažanovyj* "dark purple aubergine"). Two other BCTs with rich derivational productivity are *sinij* "dark blue" (F: 261, M: 268) and *goluboj* "light blue" (F: 259, M: 178), evidencing Russian speakers' categorical—and linguistic—refinement of the BLUE area.[2,3,20]

3.6 | Russian "purple" terms

As mentioned in the Introduction, the PURPLE area in Russian is denoted by multiple nonbasic terms.[2,3,22,23,28] To further explore this, we compared percentages of occurrence of the ten most frequent "purple" monolexemic color names, in females and males (Figure 8). The ranks of these terms, based on frequency of occurrence, are presented in Table 4.

Note that, along with nonbasic "purple" terms reported pre1990s—*sirenevyj*, *bordovyj*, *malinovyj*, *lilovyj*, and *višnevyj*—the modern Russian inventory has expanded to include *fuksiâ* "fuchsia" (with relatively high rank 30 for females) and *madženta* "magenta", while 3 "classic" terms diminished, when one compares respective rankings obtained by Davies and Corbett[18] and in this study: *purpurnyj* "cardinal red" (rank 20 → 47 for females); *višnevyj* "cherry-colored" (rank 24.5 → 115 for females, 140 for males); *bagrovyj* "crimson" (rank 54.5 → 136).

TABLE 3 Derivational productivity of the 12 Russian BCTs, for females and males

	Females		Males	
Russian BCTs	**Total number of unique polylexemic descriptors**	**Frequency of occurrence of polylexemic descriptors**	**Total number of unique polylexemic descriptors**	**Frequency of occurrence of polylexemic descriptors**
belyj	30	35	23	31
čërnyj	14	17	13	15
krasnyj	33	76	38	133
žëltyj	48	160	43	146
zelënyj	88	396	80	397
sinij	65	261	54	268
koričnevyj	53	172	37	162
fioletovyj	61	314	55	313
rozovyj	93	436	64	332
oranževyj	33	87	25	58
seryj	46	241	49	202
goluboj	64	259	42	178

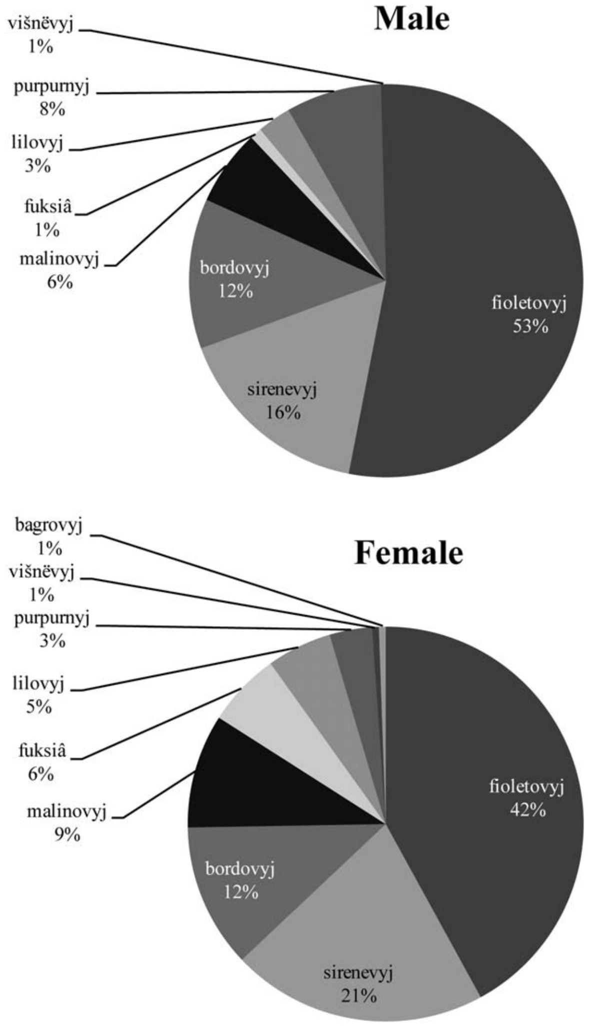

FIGURE 8 Percentage of occurrence of most frequent Russian color names for the PURPLE area elicited in females (top) and males (bottom)

3.7 | "Color of X" terms in modern Russian

Following the suggestion that new color terms are derived from names of color objects and enter the language gradually, initially conforming to the pattern *cveta X* "color of X",[27] we explored the dataset from this perspective. For both genders, a very frequent and entrenched object-derived Russian term is *cvet morskoj volny* "color of sea wave", a close synonym of *birûzovyj* "turquoise" (cf. reference2).

Women used the pattern "color of X" in 23 different combinations (50 cases) to denote fuchsia (*cvet fuksii*), khaki (*cvet khaki*), asphalt (*cvet asfal'ta*), ripe cherry (*cvet speloj višni*), among others, along with emotionally-laden, 'poetic' terms, alluding, for example, to the color of a murky sky (*cvet pasmurnogo neba*), a light blue wave (*cvet goluboj volny*), fresh grass (*cvet svežej travy*), juicy green (*cvet sočnoj zeleni*), so forth.

The pattern "color of X" was used by men in 25 different combinations (36 cases); among these relatively frequent were those denoting skin color (*cvet koži*), dry grass (*cvet suxoj travy*), graphite (*cvet grafita*), loam (*cvet suglinka*), mint (*cvet mâty*), sea water (*cvet morskoj vody*), green cabbage (*cvet zelënoj kapusty*), or manganese crystals (*cvet margancovki*) and the brilliant green (*cvet zelënki*) (the 2 latter are widely used by Russians as natural pharmaceutical products). Significantly less frequent were idiosyncratic or exotic compounds, such as water (*cvet vody*), radish (*cvet rediski*), night sky (*cvet nočnogo neba*), dark conifer forest (*cvet tëmno-khvojnogo lesa*), sea salt water (*cvet morskoj solënoj vody*), Uruguay pampas (*cvet urugvajskix pampasov*), fox hair in books (*cvet lis'ej šersti v knigax*), so forth.

3.8 | Consistency of color descriptors: females versus males

As indicated in the "Methods" section, for each participant 1 randomly selected color sample was presented twice to measure response consistency. Since color naming was unconstrained, 2 measures of consistency were calculated (cf. reference 57). Specifically, we estimated fully consistent use of color names (Figure 9, left). In addition, we distinguished between instances when an observer used 2 noncognate names for the color in question (eg, *zelëno-želtyj* "green-yellow" versus *gorčičnyj* "mustard-colored") and those when different color names were used but these contained a common hue component (eg, *krasnyj* "red" vs. *tëmno-krasnyj* "dark red"). For an extended analysis the latter names were considered as consistent (Figure 9, right). In this study men appeared to be slightly more consistent in their responses but the difference was nonsignificant ($\chi^2 = 0.06$, $P = .81$, using Yate's correction). This tendency is at odds with previous studies[38,39,42,58] for English speakers that showed women's higher naming consistency and may be explained by more frequent use of nonbasic and "fancy" terms or polylexemic descriptors by females.

TABLE 4 Ranks of frequent Russian color terms used for naming the PURPLE area

Russian term	Gloss	Females	Males
fioletovyj	purple	1	1
sirenevyj	lilac	7	10
bordovyj	claret	13	14
malinovyj	raspberry	14	24
lilovyj	mauve	27	39
fuksiâ	fuchsia	30	90
purpurnyj	cardinal red	47	20
višnevyj	cherry-colored	115	140
bagrovyj	crimson	136	136
madženta	magenta	174	491

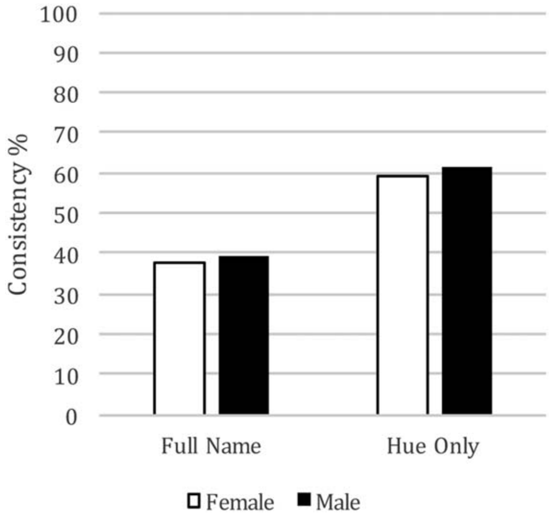

FIGURE 9 Consistency of responses to repeated color samples for females and males

3.9 | RTs for the Russian BCTs and frequent nonBCTs: females versus males

RTs for 25 most frequent Russian color names, separately for each gender, are shown in Figure 10. It demonstrates that RTs were shorter for almost all BCTs compared with nonBCTs (with an exception of nonbasic *alyj* "scarlet"). A Mann-Whitney U test indicated that, across color names, RTs (estimated by medians and semi-interquartile ranges, sIQR) did not differ significantly between females (Med = 6.04, sIQR = 1.82) and males (Med = 6.08, sIQR = 2.26), $U = 895$, $P = .77$.

3.10 | Synthetic image: color naming segmentation by females versus males

To visualize gender differences in Russian color naming, a probabilistic algorithm based on Maximum a Posteriori (MAP) was used.[55] For each color name y from a set of Russian color names $y_1 \ldots y_T$ offered by males and females in our experiment more than 20 times, we calculated the empirical mean μ_y and variance-covariance matrix Σ_y of test colors $x_1, \ldots, x_n$. We could then estimate the probability density function by:

$$\hat{f}_{\text{norm}}(x|y) = \text{const}_y \exp\left(-\frac{1}{2}(x-\mu_y)^{\text{T}}\Sigma_y{}^{-1}(x-\mu_y)\right), \quad x \in \{x_1, \ldots, x_n\} \tag{1}$$

where x is the test color specified by the triplet $x = (x_{(L)}, x_{(a)}, x_{(b)})^T$ and const_y is a normalizing factor that depends on μ_y, Σ_y and $x_1, \ldots, x_n$ and ensures that the sum of the probability distribution is equal to 1. Using Bayes' theorem, the MAP estimator can then be defined as:

$$\hat{y}_{\text{MAP}}(x) = \underset{y \in \{y_1, \ldots, y_T\}}{\arg\max}\left(\frac{\hat{f}_{\text{norm}}(x|y) \cdot \hat{f}(y)}{P(X=x)}\right) \tag{2}$$

MAP favors color names with high probability $\hat{f}(y)$ or high normalization factor const_y to maintain congruence between the observed and predicted data. This means that μ_y is not necessarily equal to the mean of $\hat{f}_{\text{norm}}(x|y)$ and frequent and consistent color categories tend to subsume less common or inconsistent neighboring categories.

The algorithm was trained separately by the Russian female and male datasets to segment a synthetic image constructed as a diagonal slice through CIELAB[59] to include the most saturated regions of color space, as shown in Figure 11. Coordinates of the centroids of the most frequent descriptors were used to color each name category in the synthetic images for females and males.

The model predicted that females would use a richer color vocabulary to classify the synthetic image than males. As illustrated in Figure 11, female linguistic segmentation (middle) is more refined, particularly, in the upper half of color space, compared with that of males (right). Figure 12 provides the full list of the segmented categories, 27 for females and 19 for males. Figure 11 visualizes sufficiently large segments (19 for females; middle; 15 for males; right).

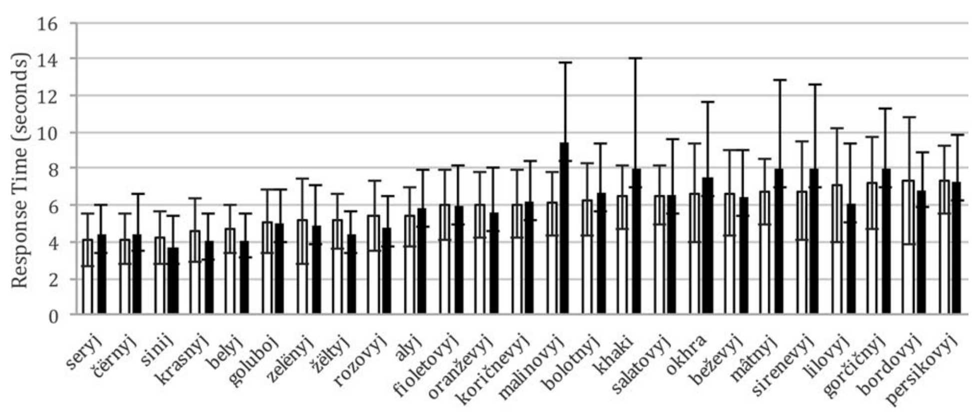

FIGURE 10 Median RTs for most frequent Russian color names for females (white) and males (black) ordered by median RTs for females. Bars indicate sIQRs

FIGURE 11 Left: Synthetic image of color space.[55] Segmentation of synthetic image for Russian speakers: Middle, Females; Right, Males

As indicated by the list of the segmented categories (Figure 12), inter-gender linguistic-density differences are mainly along the red-green axis of color space. Specifically, females tended to lexically differentiate predominantly "warm" colors: they single out "hot" pink (*jarko-rozovyj* "bright pink") and use frequent nonbasic terms, referring to colors of natural objects (*malinovyj* "raspberry", *persikovyj* "peach", *gorčičnyj* "mustard-colored", *fuksiâ* "fuchsia") or substance (*pesočnyj* "sand-colored"). In comparison, men revealed refined denotation of "military" colors (*khaki* "khaki", *sero-zelënyj* "gray-green", *grâzno-žëltyj* "dirty yellow").

4 | DISCUSSION

The present outcome for Russian color naming in the online experiment provided satisfactory agreement when validated against earlier lab-based and web-based experiments for English speakers.[38,53]

4.1 | Russian versus English color names: cross-language differences

4.1.1 | Basic color terms

Several departures of centroids for the Russian and English BCT counterparts were found. An inspection of the 3D CIELAB plot (Figure 3, bottom) shows that, in accord with previous findings, Russian *goluboj* and *sinij* are lighter and darker, respectively, than English *blue*.[23,24,31,32] Also, centroids for *sinij* and *goluboj* are separated along the 2 chromatic dimensions (cf. reference 28). In particular, as is obvious in the *a*b** projection (Figure 3, top), in hue Russian *goluboj* is

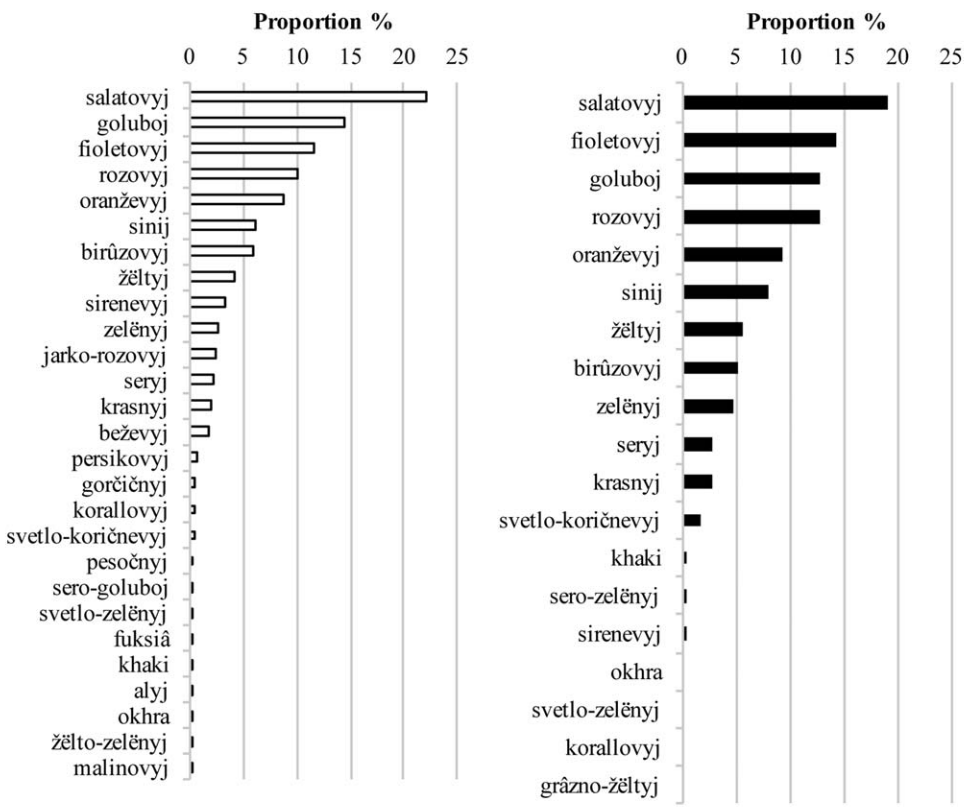

FIGURE 12 Most frequent Russian color names lexicalizing areas in the color space synthetic image, for females (left) and males (right)

closer to English *blue* and is "greener" than *sinij*. Conversely, the centroid of *sinij* is closer to the centroid of *purple* and is "redder". Similar clustering of Russian *fioletovyj* and *sinij* was recently shown based on analysis of listing task data.[51]

The centroid for *fioletovyj* is very close to that for English *purple*, thus empirically confirming that Berlin and Kay's nomination of *fioletovyj* as the Russian counterpart of the latter was correct. It also appears that Russian *krasnyj* is lighter and more vivid than English *red*.

Both web-based studies, in Russian and English, indicate that the centroids for "yellow" are "greener" and lighter compared with that in the lab-based study of Sturges and Whitfield,[53] a discrepancy that might be due to differences in sampling the GREEN and YELLOW areas by the corresponding stimulus sets. Thus, we cannot exclude that some of the delineated discrepancies are manifestations of differences in methodology rather than of genuine cross-language effects.

Color presentation media

In this study, as in the English-naming web-based experiment,[55] self-luminous monitor colors were employed, compared with surface colors, the gloss Munsell samples used by Sturges and Whitfield.[53] Note that color naming is impacted by the presentation media: as demonstrated by Hedrich and Bloj,[60] the naming agreement between the 2 presentation media varies between 65% and 82%; the reason for the discrepancy supposedly depends on the illuminant of surface colors implying differences in stimulus spectral composition.

Variation of the color-naming method

In the present study, the UCN was employed, allowing polylexemic color descriptors, unlike monolexemic naming (MN) in the Sturges and Whitfield[53] study. In an earlier study[61,62] that compared the 2 method variations, while employing the same stimulus set and participants, the UCN was shown to result in greater naming refinement and precision. Notably, polylexemic terms, with modifiers, compounds or object glosses, were predominantly used to denote hard-to-name colors, that is, less saturated colors in the "inner core" of color space and colors straddling BCT boundaries. Consequently, color space areas denoted by BCTs become more circumscribed and include only "better", saturated examples of the category, and BCT centroids (category "centers of gravity") are expected to be shifted to areas of saturated colors, closer to the gamut perimeter.

4.2 | Richness of Russian nonBCTs

Russian color inventory is rich in frequently used secondary color terms, as evidenced in linguistic[16,20,25–27,30] and psycholinguistic studies.[2,23,25,26,28] Among these are terms such as the high frequency s*alatovyj* "lettuce-colored", *birûzovyj* "turquoise", *cvet morskoj volny* "sea wave color" and *kirpičnyj* "brick-colored" (see Table 2 in reference28).

Notably, the most frequent nonbasic terms *sirenevyj* "lilac" and *birûzovyj* "turquoise", revealed in this study for Russian speakers, have equally high cognitive salience in color vocabularies of both genders, which is similar to findings on counterparts of these nonbasic terms in English[53,63] and German.[64] Mylonas and MacDonald,[15] who reported a composite index of basicness for 30 most frequent English monolexemic color terms, suggest an extension of the English color inventory from the 11 BCTs to 13, augmented by *lilac* and *turquoise*.

Uusküla and Bimler,[51] who reconstructed clusters of most frequent color terms according to their cognitive salience, found a recurring dichotomy in the way the glosses for "lilac" and "turquoise" are conceptualized in 14 European languages, including Russian. In particular, it was found that, with regards to its cognitive salience, Russian *birûzovyj* clusters with the 2 most frequent "purple" nonBCT, *sirenevyj* "lilac" and *lilovyj* "mauve". In other languages, in comparison, glosses for "turquoise" belong to a cluster of either "blues" (eg, in Estonian or Hungarian) or "greens" (eg, in Italian); their cognitive salience is lower and comparable to that of "beige", "gray", or terms denoting metallic sheen (Turkish, Spanish, Swedish, Finnish, Czech).

The high salience of nonbasic *sirenevyj* is suggested to be a consequence of the existence of the 2 Russian BCTs for "blue" complemented by 2 "purple" terms: while *fioletovyj* "purple" designates the intersection of *sinij* "dark blue" with red, the intersection of *goluboj* "light blue" with red is lexicalized by *sirenevyj*.[3,24]

4.3 | Differences in the naming strategies between Russian and English speakers

Russian speakers have a higher frequency of single-word color-term usage than English speakers. The latter use much more frequently modifiers and compounds of both BCTs and nonbasic monolexemic terms. This can be indicative of differences in naming strategies between Russian and English in the use of polylexemic names.

This finding of Russian speakers relying more frequently on MN is surprising and counterintuitive in view of the findings of Vasilevich,[21] Rakhilina,[25] Kul'pina[65,66] and, also, more recent findings that demonstrate color-naming expressive complexity in modern Russian language (cf. references[67–71]). Richness and linguistic elaboration in color naming by Russian speakers is also confirmed by our response set, containing numerous complex and expressive names, such as *cvet osennej travy* "color of autumn grass" or *asfalt na zakate* "asphalt color at sunset".

The frequent use of monolexemic CTs found in the present experiment may disguise the fact that these can serve to communicate denotative meaning with great specificity due to two factors. First, Russian possesses a great variety of (non)BCTs to denote color space subareas that in English require a compound term (eg, *goluboj* vs. *light blue*; *vasil'kovyj* vs. *cornflower blue*; *salatovyj* vs. *lettuce-colored*; *gorčičnyj* vs. *mustard-colored*; *brusničnyj* vs. *cowberry-colored,* etc.). The great variety of Russian monolexemic nonBCTs are adjectival derivatives of object glosses. Although in English a new color term (adjective) emerges as an equivalent of the "parent" object, without any change in the grammar form (eg, *coral*), in Russian several adjectival forms are derived from the noun of the "parent" object (eg, *korall* "coral" → *korallovyj*; *baklažan* "aubergine" → *baklažannyj* or *baklažanovyj*,[68] p. 59).

Second, monolexemic color names, along with other Russian adjectives, can be modified by various diminutive or expressive suffixes (*-at-*, *-en'k-*), which enables the conveyance of specific nuances of the CT meaning (eg, *krasnyj* "red" vs. *krasnovatyj* "reddish"; *oranževyj* "orange" vs. *oranževen'kij* "~joyful, nonprominent [of extent] orange") (cf. references[65,67–69]).

4.4 | Female versus male color naming in Russian

Analysis of gender differences in the outcome of the present color-naming experiment in Russian confirmed the findings of previous offline studies of English speakers that women exceed men in the richness of their color lexicon[37,38,40–42,45,72–75]; however, we found no evidence that women exceed men in regard to color-naming speed.[76–78] Despite naming having been unconstrained, unmodified BCTs were produced often by females and males alike and were used more consistently and named faster than other terms.

Mean centroid difference between Russian speakers of 2 genders is lower than the difference between centroids for English females and males. The higher value in the latter case might have resulted from methodological aspects of Mylonas et al.'s study,[38] viz. lower numbers of participants (F: 159, M: 133) and/or denotative variation of BCT concepts among speakers of English across the world (UK, USA, Australia, Canada, etc.), whose data were pooled for the analysis. Alternatively, the smaller inter-gender difference obtained here may reflect genuinely higher consensus among Russian speakers due to a culturally entrenched color-naming strategy.

The genders do differ, however, in the the pattern and variety of elaborated color terms. Specifically, men demonstrated a higher percentage of occurrence of BCTs, whereas women used more often monolexemic nonBCTs (eg, *beževyj* "beige", *persikovyj* "peach"). Investigation of the PURPLE area in this study reveals different mapping structure of this area by men and women: whereas men often use BCT *fioletovyj* "purple", women prefer monolexemic nonBCTs, such as *sirenevyj* "lilac" or *fuksiâ* "fuchsia".

Females' frequent color terms, revealed by segmentation of the color space synthetic image, are descriptive and derived from object glosses—names of domesticated or wild plants (such as *malinovyj* "raspberry", *persikovyj* "peach", *fuksiâ* "fuchsia"), food (*gorčičnyj* "mustard-colored") or natural materials (*pesočnyj* "sand-colored", *korallovyj* "coral"). The tendency for women to use significantly more descriptive than abstract color terms was also previously observed in Russian[46,47] and German.[48] Notably, among Russian descriptive color terms those designating the "warm" part of the spectrum dominate.[21,23,25,28] This is also in accord with observations on color vocabularies in English,[4] Hungarian,[79] and Italian.[80]

To a great extent gender differences in color naming are considered to have social and cultural origins: due to predominant upbringing patterns, women develop a greater awareness of color, reflected by its elaborated linguistic representation, and a finer appreciation of differences between colors.[28,47] The similarity of inter-gender differences in color lexicon of Russian speakers (this study) and English speakers[37–45,73–75] may, though, reflect both "nurture", that is, gender-specific patterns of socialization, similar in modern Russian society and the Anglo-Saxon world, and the "nature" origin of the phenomenon, that is, genetically determined inter-gender differences in the visual system (summarized in reference38).

4.5 | Ongoing changes in color term usage in modern Russian

The Russian National Corpus (www.ruscorpora.ru; 18th to 21st centuries) records the ongoing emergence of new color terms in the Russian color lexicon and increase of use of previously infrequent terms. Among color descriptors offered in the present experiment, terms that are relatively new in the Russian color vocabulary are not infrequent, such as *lajm* "lime", *fuksiâ* "fuchsia", *madženta* "magenta", *lavandovyj* "lavender", etc. Another observed tendency, especially in youth lexicon, is shortening of existing adjectival color terms to their noun stems, the phenomenon predominantly relating to adjectives derived from objects (eg, *nebesnyj* → *nebo*, *šokoladnyj* → *šokolad* "chocolate-colored" or *baklažanovyj* → *baklažan* "aubergine-colored", etc.), that is, the method of derivation typical in English. These changes appear to have emerged or accelerated after 1991, that is, in the post-Soviet era, and result from the significantly intensified trade/marketing contacts with English-speaking partners, accompanied by a great influx of western products, whose advertisements often include English color names transliterated into Russian.[21,71,81]

Further work and additional analysis is required to investigate Russian nonbasic terms denoting colors straddling the boundaries between BLUE and GREEN or PURPLE and RED areas of color space—the regions demonstrated to be much more linguistically refined in Russian compared with other languages, with the potential for further emerging BCTs.

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